THE NICKEL BULLETIN

A MONTHLY SUMMARY OF CURRENT INFORMATION

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Glossary of Terms Relating to Mechanical Testing

AMER. SOC. TESTING MATERIALS, COMMITTEE E-1 ON METHODS OF TESTING: 'Proposed Revised Tentative Definitions of Terms Relating to Methods of Mechanical Testing.'
Contained in *A.S.T.M. Preprint 54*, June, 1954, pp. 17–20.

The schedule contains twenty-one definitions of terms used in tensile, hardness, and shear testing.

Rapid Hardness Testing of Metallic Materials: A.S.T.M. Recommendations

AMER. SOC. TESTING MATERIALS, COMMITTEE E-1 ON METHODS OF TESTING: 'Proposed Tentative Method of Rapid Indentation Hardness Testing of Metallic Materials,'
Contained in *A.S.T.M. Preprint 54*, June, 1954; pp. 14–16.

The schedule covers a test in which a specified load is applied to the surface of a material through a hard ball of specified diameter and a measurement of the impression is made, either while the load is being applied or after it is removed, to determine whether the material falls within certain required limits. The test is intended for use in cases in which it is desired to make very rapid determination of hardness, as in the inspection of the output of a heat-treating furnace, when precise hardness values are not necessary. The method is *not* to be regarded as a standard Brinell hardness test procedure. Loads of 3000, 1500 and 500 kg. are proposed, depending upon the hardness of the material under test: it is desirable that the test load be of a magnitude such that the diameter of the impression is in the range of 25·0 to 47·5 per cent. of the ball diameter.

Softening of Cold-Worked Metals under Fatigue Conditions

N. H. POLAKOWSKI and A. PALCHOUDHURI: 'Softening of Certain Cold-Worked Metals under the Action of Fatigue Loads.' *Amer. Soc. Testing Materials, Preprint 74*, June 1954; 12 pp.

Fatigue of ductile metals is usually believed to be associated with progressive strain-hardening, but the authors of this paper show that although this is true for initially unstrained metals the opposite effect is likely to occur in fatigue of metals which have been initially cold worked. In the experiments reported, copper, nickel, aluminium, tin, bronze, 80–20 cupro-nickel, an aluminium alloy, and a non-ageing titanium-killed steel were first cold-drawn 20–40 per cent., to 0·2 in. diameter, and then subjected to alternating tension-compression fatigue stressing at frequencies of 5500 to 9500 c.p.m. Compression tests and determinations of Vickers hardness on the fatigued specimens showed more or less pronounced softening in all cases.

The observations made are discussed in the light of previous work on the Bauschinger effect and its manifestations, and an interpretation of the authors' findings is proposed, on a pure stress-strain basis. It is suggested that fatigue failure of a cold-worked metal may be attributed to the breakdown of the initially high elastic properties under cyclic strain, and to resulting semi-plastic behaviour. Cyclic plastic flow would facilitate the coalescence of vacant lattice sites into larger holes, which may act as crack embryos.

Electrolytic Polishing of Metals and Alloys: Reference Data

'Conditions for Electrolytic Polishing of Metals and Alloys.' *Materials and Methods*, 1954, vol. 39, June, pp. 137, 139, 141.

Tabular summary, compiled by S. H. BUSH. The information is correlated from over 50 sources, reference to which is made in the *bibliography*. Particulars are given of electrolyte composition and operating conditions for electropolishing twenty-one metals (including nickel); aluminium-, copper-, gold-, lead-, magnesium-, nickel-, tin-, and zinc-base alloys; carbon and low-alloy steels; stainless steels of the austenitic and straight-chromium types, and cast irons (white, nodular and grey).

The June issue of *Materials and Methods* also contains an article by M. W. RILEY, entitled 'Where and When to Use Electropolishing'. This describes some of the factors which must be considered when using the electropolishing method, and illustrates some of the unusual applications for which this procedure can successfully be employed.

Determination of the Liquidus Points of Alloys

W. HUME-ROTHERY and D. M. POOLE: 'Methods for Determining the Liquidus Points of Titanium-Rich Alloys.' *Jnl. Inst. Metals*, 1953-54, vol. 82, June, pp. 490-2.

The authors describe two methods for determining the liquidus points of alloys of titanium or other metals which are too reactive for the use of conventional thermal analysis. Experiments with a titanium-nickel alloy containing about 23·5 at. per cent. of nickel are described.

Production of Pins from Wire

See abstract on p. 126.

NICKEL

Extraction of Nickel from Lateritic Ores: The Nicaro Plant

G. P. LUTJEN: 'Nicaro Proves Lateritic Nickel can be Produced Commercially.' *Engineering and Mining Jnl.*, 1954, vol. 155, June, pp. 81-9.

This article gives an account of the history of the Nicaro project, from the essentially technical aspect, discussing the problems which have arisen in treatment of the low-grade Cuban ores, and some of the methods adopted for their solution. The plant operations are serially described, with detailed flow sheet. Nicaro is currently producing 80,000 lbs. of nickel per day as nickel oxide, from the 4,000 tons of limonite-serpentine delivered from the mine. Plans for expansion are under way.

Electric-Smelting of Low-Grade Nickel Ores

'Continuous Electric Smelting of Low-Grade Ores.' 'Continuous Selective Reduction Tests on Nickel Ores.' *Mining Jnl.*, 1954, vol. 242, Apr. 9 and 16, pp. 415-16, 447-8.

These articles are based on U.S. Bureau of Mines Report of Investigations 5201, which gives an account of methods developed for extraction of nickel from ores of low metal content, such as those found in the Cle Elum deposit (near Seattle), in the Riddle deposit in S.W. Oregon, and in some other areas. An account is given of the structures of the ores, preliminary tests carried out in developing the treatments to be adopted, electric-smelting procedures, and the results of electric smelting and refining and upgrading experiments. Results of the tests indicate that ferronickel produced from such low-grade ores can be upgraded to virtually any desired nickel content, by a selective oxidation of the iron, and it is also possible to produce a refined ferronickel of sufficiently low sulphur content to be suitable as an addition material, e.g., as a late addition in high-alloy steel.

Intensity Measurements in the Arc Spectrum of Nickel

R. L. HEID and G. H. DIEKE: 'Intensity Measurements in the Arc Spectrum of Nickel.' *Jnl. Optical Soc. of America*, 1954, vol. 44, May, pp. 402-10.

The relative intensities of 478 nickel arc lines were measured photoelectrically between 3359 and 5893 Å, with an accuracy better than one per cent. for the good lines.

Lattice Structure of Nickel and Iron

F. W. VON BATCHELDER and R. F. RAEUCHLE: 'Re-Examination of the Symmetries of Iron and Nickel by the Powder Method.' *Acta Crystallographica*, 1954, vol. 7, May 20, p. 464.

In 1949, KOCHANOVSKA, when determining the lattice constant of iron from several reflecting planes, reported significant differences between measured values for the different planes above 250°C. The findings were attributed to a deviation from cubic symmetry (*Physica*, 1949, vol. 15, p. 191). Work by the present authors, reported in this note, was carried out on iron, with confirmatory experiments on nickel. Their results, however, lead to the conclusion that 'there is no significant difference among the lattice constants of iron calculated for the various planes at any temperature'. Their data do not, therefore, support the conclusions of KACHANOVSKA. Observations made by them on nickel confirm those for iron.

Effect of Elastic Strain on Electrical Resistance of Nickel and Nickel Alloys

G. C. KUCZYNSKI: 'Effect of Elastic Strain on the Electrical Resistance of Metals.' *Physical Rev.*, 1954, vol. 94, Apr. 1, pp. 61-4.

The strain coefficients of electrical resistivity of wire specimens of eighteen metals and alloys were experimentally determined, and it was shown that for most of the materials tested the free-electron theory accounts qualitatively for the effects observed. The metals on which the determinations were made included nickel in various conditions. A series of copper-nickel alloys was also tested: in this group the nickel contents were 1·08, 11·50, 45·00, 72·00, 96·00, 98·30 and 99·50 at. per cent.

Adsorption of Water Vapour on Nickel

A. C. ZETTLEMOYER and J. J. CHESSICK: 'Adsorption Studies on Metals. III. The Sorption of Water Vapor on Nickel, Steel and Molybdenum.' *Jnl. Physical Chemistry*, 1954, vol. 58, Mar., pp. 242-5.

Report of study of the oxide films present on the surface of nickel, steel, and molybdenum, using both gas-adsorption and calorimetric techniques. Nickel powder degassed at 25°C. was found to exhibit only physical adsorption of water vapour, and the heat of emersion in water was about 550 ergs/cm². Degassing the nickel powder at 300°C. removed a strongly bound layer of water and raised the heat of emersion to 950 ergs/cm².

Adsorption of Gases on Nickel Oxide

R. M. DELL and F. S. STONE: 'The Adsorption of Gases on Nickel Oxide.' *Trans. Faraday Soc.*, 1954, vol. 50, May, pp. 501-10.

The investigation was made on thin films of nickel oxide present as a layer on nickel metal. The heats of adsorption of oxygen, carbon monoxide and carbon dioxide were measured calorimetrically, and the formation of an adsorbed complex having a formula CO_3 was studied in detail. The catalytic oxidation of carbon monoxide, which proceeds at 20°C., was briefly investigated: the results were correlated with the data on adsorption.

On heating *in vacuo* adsorbed oxygen is removed by incorporation as nickel oxide rather than by desorption. Adsorption of oxygen is therefore to be regarded as the first stage in the further oxidation of

the underlying metal. The degree of regeneration of the surface, however, depends critically on both the temperature of baking out and the thickness of the oxide film. These results are discussed in terms of the mechanism of the oxidation process and the properties of nickel oxide as a semi-conductor.

Electrolytic Polishing of Metals and Alloys: Reference Data

See abstract on p. 124.

Behaviour of Nickel in Contact with Molten Sodium Hydroxide

See abstract on p. 149.

Flicker Noise in Oxide-Coated Cathodes

W. W. LINDEMANN: 'Influence of Different Activating Agents on Flicker Noise in Oxide-Coated Cathodes.' *Bull. Amer. Physical Soc.*, 1954, vol. 20, June 28, p. 26.
Abstract of paper to American Physical Society, June, 1954.

Report of a series of experiments made to determine the variations in flicker noise characteristic of tubes having various types of nickel-alloy cathode. Of the materials used (INCO 220, INCO 225, nickel containing 0·1 per cent. of aluminium, nickel containing 0·4 per cent. of tungsten, and 499 nickel), the 0·1 per cent. aluminium material consistently gave the least noisy tubes. The paper also contains details of some other characteristics of the cathode materials which may explain the variations in flicker noise.

Oxide-Impregnated Nickel-Matrix Cathode

W. BALAS, J. DEMPSEY and E. F. REXER: 'An Oxide-Impregnated Nickel-Matrix Cathode.'
Bull. Amer. Physical Soc., 1954, vol. 20, June 28, p. 29.
Abstract of paper to American Physical Society, June, 1954.

In the method described by the authors, a sintered nickel matrix of controllable porosity is prepared, and is impregnated with solutions which precipitate a mixed carbonate within the matrix. The cathodes so made can be activated by methods approximately similar to those used for normal oxide-coated types.

Production of Nickel Pins

'The Production of Headed Pins.' *Machinery* (*Lond.*), 1954, vol. 84, May 14, pp. 1021–4.

The article gives a detailed and well illustrated description of methods used in the works of Wire Products and Machine Design, Ltd., in making headed pins and cut wire for various purposes. Of the total output from these works a large proportion is in nickel pins for miniature valves. These are made from wire of 0·040-in. diameter, which is cut into lengths of 0·315 in. The ends are rounded in a special machine developed by this Company. Up to 4,000,000 such pins are made per week, for welding to lengths of nickel-iron alloy wire which, in turn, are welded to lengths of wire for valve-input leads. Typical assemblies are illustrated in this article. Other forms of nickel pin are also shown, together with details of some of the special machines employed for processing the wire products. Reference is also made to production of very short lengths of steel wire, for use in shot blasting.

Nickel-Clad Steel Tanks for Marine Transport of Caustic Soda

See abstract on p. 155.

Gas-Shielded Arc Processes for Cutting Nickel and its Alloys

See abstract on p. 133.

Joining of Tubes to Tube Sheets: Procedures Suitable for Various Materials

See abstract on p. 141.

Colorimetric Determination of Nickel

J. M. CHILTON: 'Simultaneous Colorimetric Determination of Copper, Cobalt and Nickel as Dithiocarbamates.' *Analytical Chemistry*, 1954, vol. 26, May, p. 940.

Further work by the author has resulted in several modifications of the procedure described *ibid.*, 1953, vol. 25, pp. 1274–5 (see abstract in *Nickel Bulletin*, 1953, vol. 26, No. 10, p. 165). Particulars are given in this note of the changes, which make the method more applicable to solutions containing large amounts of uranyl ions.

Chromatographic Method for Determination of Small Quantities of Nickel

S. V. VAECK: 'Quantitative Inorganic Paper Chromatography. Direct Determination of Nickel in Microgram Quantities.' *Analytica Chimica Acta*, 1954, vol. 10, Jan., pp. 48–67.

The author describes a method for direct determination, on filter paper, of nickel, after chromatographic separation of interfering elements. The sample is dissolved in 3-*N* hydrochloric acid and a spot of the solution is placed on filter paper, together with drops of standard solutions of nickel. After chromatographic development with a mixture of acetone, hydrochloric acid and acetylacetone, the nickel spot (which remains practically stationary, whereas the majority of the other cations move away some distance on the paper) is made visible by spraying with a solution of rubeanic acid, and its reflectance is measured with a Beckman DU spectrophotometer at 625 mμ. In the presence of large amounts of aluminium, chromium, titanium, or vanadium preliminary extraction of the nickel is necessary. Comparison of results obtained by the method recommended, with those found by chemical methods, indicates a high degree of accuracy.

Softening of Cold-Worked Nickel under Fatigue Conditions

See abstract on p. 124.

Influence of Trace Elements on Oats

J. G. HUNTER and O. VERGNANO: 'Trace-Element Toxicities in Oat Plants.' *Ann. Applied Biology*, 1953, vol. 40, Dec., pp. 761–77.

Investigations on the toxicity associated with certain soils in Aberdeenshire, developed on a mixed drift derived largely from ultrabasic igneous rocks in which serpentine predominates, showed that the soils and plants grown on them contained excessive concentrations of nickel, and that other trace elements, e.g., cobalt, chromium, and zinc, were also present in abnormal concentrations, though probably not at toxic levels.

Excessive amounts of all the elements mentioned, when supplied in nutrient solutions to oat plants in sand culture, were found to produce (*a*) chlorosis, and (*b*) other symptoms specific to the element involved. The toxic effects of nickel, cobalt, copper, zinc, manganese and molybdenum are associated with high concentrations of the element in the leaf tissue, but this is not always so in the cases of chromium and aluminium. The toxic effects of nickel, chromium, copper and molybdenum are associated with a reduced nitrogen content of the plant. Nickel, cobalt, chromium, zinc, and manganese increase the concentration of phosphorus in the tissue, whereas aluminium decreases it, probably to a deficiency level.

With regard to the influence of other elements on the effect of nickel, the authors found that aluminium reduces the intensity of the symptoms produced by nickel, probably by reducing the uptake of nickel and phosphorus. Copper effectively reduces the leaf necrosis produced by nickel, but not the nickel content of the leaf tissue. The other elements named slightly increase chlorosis resulting from excessive nickel. The relative order of the elements in producing chlorosis is discussed in relation to iron deficiency.

Nickel Carbonyl Hydride

H. BEHRENS and F. LOHÖFER: 'Nickel Carbonyl Hydride ($NiH(CO)_3)_2$: a New Type of Carbonyl Hydride.' *Zeitsch. f. Naturforschung*, 1953, vol. 8b, Nov., pp. 691–2.

The carbonyl hydride described is prepared by reaction of nickel tetracarbonyl with metallic sodium, in liquid ammonia.

Nickel Salts of Sebacic Acid

P. N. CHEREMISINOFF and M. L. STUMPF: 'Study of Properties of Metallic Salts of Sebacic Acid.' *Amer. Paint Jnl.*, 1954, vol. 38, Jan. 25, pp. 107–8.

Although there has been wide interest and a considerable amount of publication on metallic salts of mono-basic fatty acids, relatively little reference has been made in the literature to salts of di-basic acids. The purpose of the study presented in this paper was to extend the scant information available on these salts, to determine their gelling characteristics, and to investigate their physical and other properties, in order to compare them with the properties of mono-basic metallic salts of fatty acids. The di-basic acid the salts of which were studied was sebacic acid: the method used in preparation of the salts is described. It comprised essentially the double decomposition or precipitation procedure used in the manufacture of metallic stearates. Properties are listed for twenty metallic sebacates, including nickel sebacate.

ELECTRODEPOSITION AND OTHER COATING METHODS

U.S. Specifications for Metal Coatings and Surface Treatments

N. E. PROMISEL and D. M. PROMISEL: 'Government Finishing Specifications. An Explanation and Digest Relating to Metal Coatings and Surface Treatments (other than Organic Coatings).' *Metal Finishing*, 1954, vol. 52, May, pp. 61–70; June, pp. 95–101: see also supplementary list, *ibid.*, July, p. 73.

The authors preface this useful summary by some general comments on the nature and scope of Government specifications, and on the impossibility of narrow standardization to a single series, in view of the differing requirements of individual industries.

The first section of the review contains concise notes on the major types of specification issued under the auspices of U.S. Government Departments:—

Federal.
Military (MIL) and National Military Establishment (JAN) Specifications:—
Air Force–Navy Aeronautical Specifications.
Departmental Specifications issued by the Army, Navy or Air Force to meet special requirements of individual Departments.
Miscellaneous Specifications, e.g., those issued by the Bureau of Aeronautics, Bureau of Ordnance, etc.

The scope of authority of such specifications and the regulations pertaining to their issue and use, are described.

The second section of the review comprises a series of schedules for metallic coatings and metal finishes, issued by the respective authorities mentioned above. Details given include specifications for nickel-, chromium-, cadmium-, zinc- and tin-plating; also for cleaning and other surface treatments.

Salt-Spray Testing of Electrodeposited Coatings

AMER. SOC. TESTING MATERIALS, COMMITTEE B-8 ON ELECTRODEPOSITED METALLIC COATINGS: 'Salt-Spray Tests of Copper-Nickel-Chromium Deposits.' Contained in *A.S.T.M. Preprint 13*, June, 1954, pp. 5–16.

The salt-spray test as carried out according to A.S.T.M. Tentative Method B-117 is employed as an acceptance test in Tentative Specification A-166, which covers copper-nickel-chromium coatings on steel, but doubt has been expressed by many users of this test as to its validity in predicting the quality of such finishes. A Sub-Committee of A.S.T.M. Committee responsible for work on electrodeposited coatings therefore undertook an extensive investigation designed (1) to determine the relationship between salt-spray resistance and thickness of coating, and

(2) to determine the degree of reproducibility of salt-spray test results for coatings prepared, to identical thickness requirements, by several producers, and tested in several laboratories, using the standard apparatus and procedure laid down in Specification B-117.

Identical sets of 16 specimens were prepared, by six platers, for each of six coatings:—

On NAX low-alloy high-tensile steel

(1) 0·0015-in. nickel.
(2) copper flash +0·0015-in. nickel.
(3) 0·0009-in. copper +0·0006-in. nickel.
(4) 0·00125-in. nickel.

On carbon steel to S.A.E. 1010

(5) 0·00125-in. nickel.
(6) 0·00075-in. nickel.

A final flash of chromium was deposited on all the panels.

No restrictions were imposed on the plating laboratories, except that the samples should be prepared in accordance with the best commercial practices, and that efforts should be made to deposit uniform coatings as close as possible to the desired thicknesses. Either bright nickel or dull nickel buffed was permissible, provided that the resulting finish was comparable with that on good commercial bumpers.

The report gives particulars of the plating schedules used by some of the co-operating laboratories, and a highly detailed summary is made of the behaviour of the plated samples as tested by the various collaborators.

A critical evaluation of the information reported to the Committee shows that:—

(1) there is little or no agreement among the four testing laboratories;
(2) with regard to the rating of each plater by one individual tester, there are considerable variations, depending on the type of coating;
(3) within any one test box there was poor reproducibility of test results with respect to the panels tested in the same position;
(4) relatively few of the finishes met the requirements of A.S.T.M. A-166.

These and other findings lead the Committee to the conclusion that 'with respect to the objectives of this investigation, the tests reported have shown that the salt-spray test as operated by the four co-operating laboratories, in accordance with A.S.T.M. Method B-117, does not reliably and reproducibly prognosticate the quality of the finishes under consideration. Its value as a standard acceptance test is questionable in view of the wide divergence of test results obtained on specimens presumably plated to the same thickness by the same plater and tested by the same laboratory.'

Spray Testing: A.S.T.M. Proposals for Modification

AMER. SOC. TESTING MATERIALS, COMMITTEE B-3 ON CORROSION OF NON-FERROUS METALS AND ALLOYS: (*a*) 'Method of Acetic Acid-Salt Spray (Fog) Testing.' (*b*) 'Revision of Tentative Method for Salt Spray (Fog) Testing.' *A.S.T.M. Preprint 8*, 1954; pp. 4–10; 2.

(*a*) The Committee responsible for test methods recommends adoption of the acetic-acid modification of the salt-spray (fog) test as tentative. The solution used is to be prepared by dissolving 5±1 parts by weight of salt in 95 parts of distilled water or water containing not more than 20 p.p.m. of total solids. The salt specified is sodium chloride substantially free of nickel and copper, and containing, on the dry basis, not more than 0·1 per cent. of sodium iodide and not more than 0·3 per cent. of total impurities. The pH of this solution is to be adjusted to the range 3·2-3·5 by the addition of approximately 1 per cent. of acetic acid. The schedule covers apparatus, preparation of test specimens and their position during exposure, conditions in the salt-spray chamber, period of test, cleaning of tested specimens, and method of recording results.

(*b*) The major revision recommended in the tentative standard salt-spray test (B 117-49T) is reduction of the salt concentration from 20 to 5 per cent., proposed because more reproducible results have been obtained with the 5 per cent. solution, due to the higher relative humidity and freedom from clogging of the nozzle, which occurs frequently when the 20 per cent. concentration is used.

Nickel-Plating Problems: Summary Recommendations

O. A. STOCKER, A. KORBELAK and S. A. CARRANO: 'Nickel-Plating Troubles and Cures.' *Plating*, 1954, vol. 41, May, pp. 491–6.

The authors present a chart giving the difficulties which are liable to occur in nickel plating, the probable causes of the troubles, and suggestions for curing them. The recommendations made are based on experience in operating several hundred installations.

The subject is classified in sections relating to the following types of defect:—

Lack of adhesion (peeling).
Inadequate ductility in the deposit.
Dullness in bright-nickel deposits.
Dark deposits.
Streaky deposits.
Spotty deposits.
Deposits which are dark in recesses.
Poor throwing power and poor coverage.
Burnt edges or frosty plate.
Pitting.
Rough deposits.

Effect of Surface Finish of Basis Metals on Properties of Metallic Coatings

G. J. KAHAN, W. W. MACCHIA and J. M. FAIRBANK: 'Effect of Surface Finishing of Non-Ferrous Base Metals on the Protective Value of Plated Coatings.' *Plating*, 1954, vol. 41, June and July, pp. 649–52, 789–92.

Report issued under the aegis of A.E.S. Research Project 4.

The work described in this report was undertaken in order to extend to coatings on non-ferrous metal bases research already carried out on electroplated coatings on steel. Reference is directed to the relevant literature on the earlier investigation.

Since in commercial use the final finishing operation on a brass article is rarely polishing, but rather buffing,

satin finishing, bright dipping, or tumbling, the programme of this project was planned to study principally the influence, on electrodeposited coatings, of these methods of surface preparation of rolled-brass basis metal. It also included consideration of the fine-grained casting skin present on zinc-base die castings, as affecting the protective value of the coatings deposited on them, but for reasons given in the report this section of the investigation could not be completed.

The protective coatings used on brass were bright nickel and chromium, applied in thicknesses conforming with A.S.T.M. specifications for heaviest deposits, i.e., nickel 0·0005 in. min., chromium 0·00001 in. min.

Examination of the plated specimens after exposure leads to the conclusion that 'there was no evidence that the method of surface preparation of the rolled brass had any influence on the protective values of the subsequently applied electrodeposits. It was observed repeatedly by the inspectors that there were greater variations between panels of the same series than between the lots prepared by various methods."

American Electroplaters' Society Annual Convention: Abstracts of Papers on Nickel Plating

The following abstracts have been published of papers read and discussed at the A.E.S. Annual Convention held in New York in July: see *Plating*, 1954, vol. 41, June.

R. C. BARRETT: 'Nickel Plating from the Sulphamate Bath', p. 663.

'Historical development of the sulphamate nickel plating bath is discussed and a basic composition of a commercial bath of five years' experience is presented. Particular attention is focused upon the stress-free character of nickel deposits obtained from the sulphamate bath, along with data upon other physical properties. Specialized applications concerned with heavy metal deposition under controlled specifications are described and illustrated: these include aspects of electroplating nickel in the electrotyping, electroforming, phonograph-record and aircraft industries. Control, maintenance, operating techniques and other pertinent data on the sulphamate nickel-plating bath are described.'

L. H. CURKIN and R. W. MOELLER: 'Effects of Iron on the Physical Properties of Nickel.' p. 664.

'Stress was intentionally increased in a Watts' type nickel-plating solution by addition of fractional gram portions of ferrous chloride. Rotating-beam fatigue specimens (R. R. MOORE) plated with 0·0003 in. of nickel under these conditions showed reduction in fatigue life directly proportional to the residual stress measured on test pieces plated concurrently.'

D. MACLEAN and S. KARTEN: 'A Practical Application of Electroless Nickel Plating.' p. 665.

'A description of the complete physical layout of the production department developed for this process is given. This includes equipment used for cleaning, rinsing, plating and drying. The solutions, their control, and observations on adhesion, colour, brightness, rate of deposition, covering power, relative cost, and ease of application are fully discussed.'

W. LANDON and G. GUTZEIT: 'A Large-Scale Electroless Nickel Custom Plating Shop.' p. 666.

'The paper describes electroless nickel as a corrosion-preventive medium.'

D. T. EWING, C. J. OWEN *et al.*: 'The Effects and Removal of Lead as an Impurity in Nickel Plating Solutions.' p. 666.

'The effects of small amounts of lead present in four types of nickel-plating solution, on the appearance, adhesion, ductility, salt-spray (fog) corrosion-resistance, hardness, and throwing power of nickel deposits were studied. Watts' nickel solutions of pH 2·2 and 5·2, nickel-cobalt, and organic-brightener nickel solutions were used. In general, a tendency for all deposits to brighten occurred with increasing lead content. Adhesion remained unchanged, and ductility was not appreciably affected. An increasing lead concentration tended to increase slightly the corrosion-resistance of the heavier deposits in the salt-spray (fog) corrosion test. Removal of lead was effected through the use of low-current-density electrolysis. A high-pH precipitation also was effective, but at a pH of 5·8 the loss of nickel metal became appreciable.'

S. MODJESKA and H. FAINT: 'A Correlation of Metallurgical Hardness and Buffability.' p. 667.

'Studies were made on samples of both copper and nickel deposits, which were rated by different groups of polishers on the basis of their relative ease of buffing. Microhardness and grain structure were correlated with buffing characteristics.'

Atmospheric-Exposure Tests on Copper-Nickel-Chromium Plated Specimens

'Report of A.S.T.M. Committee B-8 on Performance Tests on Plated Specimens.' *Proc. Amer. Soc. Testing Materials*, 1953, vol. 53, pp. 256–69.

The previous report of this Committee on exposure tests of metallic coatings, published in 1951, gave inspection data on a set of copper-nickel-chromium plated panels which had been on exposure at various locations for about 3½ years. Reference was then made to a supplementary set of panels which had recently been placed on test. The present report covers final inspection data on the original set of panels (after 5·2 years of exposure), and information on the condition of the supplementary panels after exposure periods of 0·4, 1·4 and 2·4 years. Some details are given of the procedures used in plating the latter group.

The results are shown in tables giving details of general and localized corrosion, cracking, flaking and blistering of the deposits, staining, etc., and on the basis of these observations the specimens are assigned all-over ratings of quality. The methods of rating are the subject of a special section of the report and some suggestions are made for modification in future tests.

For an adequate assessment of the behaviour of the respective samples (as affected by time, nature of the atmosphere, weather, and other variables), the original must be consulted. Attention may, however, be called

to the observation that in the 1951 report it was mentioned that the application of the nickel undercoating in two steps, having the first layer buffed or annealed and buffed, had proved highly beneficial in a sea-coast atmosphere, but had not shown similar superiority in industrial atmospheres. The longer tests now reported show that such a coating is also to be preferred in rural exposure conditions. (The significance of this observation was referred to also in PINNER's paper to the Fourth International Conference on Electrodeposition and Metal Finishing; see *Nickel Bulletin*, 1954, vol. 27, No. 5, p. 89.)

Porosity Testing of Electrodeposited Coatings

N. THON and D. DEAN: 'Porosity of Electrodeposited Metals. XIII. Variation of the Gas Permeability Constant with Pressure Difference.' *Plating*, 1954, vol. 41, May, pp. 503-5.
Final report from A.E.S. Research Project No. 6.

The report describes an improved permeability apparatus, by means of which measurements have been made over larger areas of foil than could previously be examined. The apparatus has been employed to study variation of permeability as a function of the overpressure used in its determination. With increasing overpressure the permeability constant passed, in all cases, through a minimum.

Nickel Plating of Aluminium Parts Prior to Soldering

S. BAKER: 'Plating Nickel on Aluminum.' *Steel*, 1954, vol. 134, May 24, pp. 115-16: see also *Materials and Methods*, 1954, vol. 40, July, pp. 96-7.

Ford Instrument Company reports highly successful results in nickel plating of aluminium-alloy components which have to be soldered into a hermetically sealed instrument case. Nickel plating has proved superior to cadmium or copper, in that such a surface permits repeated re-sealing. The thickness of coating deposited is 0·0005 in. and it is found that it adheres to the aluminium-alloy surface at temperatures up to 500°F. (260°C.).

The cycle used in nickel plating for solder sealing is as follows:—

Degrease.
Clean in alkaline solution at 140°–180°F. (60°–83°C.) for 1–3 minutes and rinse in cold running water.
Pickle in sulphuric-acid solution, at 175°–180°F. (80°–83°C.) for 2–5 minutes, and rinse in cold running water.
Dip in nitric-acid solution at 60°–80°F. (16°–27°C.) for 1–3 minutes, and rinse in cold running water.
Sodium-zincate dip: 60°–80°F. for ½–1 minute. The work should be agitated, to ensure that all parts remain below the surface of the solution during treatment: rinse in cold running water.
Strip the zinc coating in concentrated nitric-acid solution at 60°–80°F., and rinse in cold running water.
Alkali clean at 140°–180°F. for 10–30 seconds; rinse in cold running water.
Dip in nitric-acid solution at 60°–80°F. for 1–3 minutes; rinse in cold running water.
Sodium-zincate dip at 60°–80°F. for ½–1 minute, with agitation; rinse twice in cold running water.
Nickel plate, using a current density of 5–15 amp., at 70°–90°F. (21°–32°C.). (*The composition of the bath used is not stated.*)

NON-FERROUS ALLOYS

Constitutional Studies on Binary Alloys: Bibliography

H. SPENGLER: 'History and Present Position of Research on the Constitution of Metals and Alloys.' *Metall*, 1954, vol. 8, Feb. and May, pp. 107-15, 388.

In an earlier part of this series of papers the author discussed the historical development of research on the constitution of metallic materials, concluding that much work remained to be done in the exploration of systems not yet investigated (*ibid.*, 1953, vol. 8, pp. 24-5).

The second paper (Feb., 1954) lists the binary systems on which data are available. A *bibliography* shows items published in the period 1945 to early 1953, and in the May issue additional references are given, bringing the literature up to the end of 1953. The systems referred to include twenty-five in which nickel is one of the constituent elements.

Diffusion of Other Elements in Nickel

R. A. SWALIN and A. E. MARTIN: 'Solute Diffusion in Nickel.' *Bull. Amer. Physical Soc.*, 1954, vol. 20, June 28, p. 29.
Abstract of paper to American Physical Society, June, 1954.

Report of diffusion studies of manganese, aluminium, and titanium in nickel.

H. W. ALLISON and G. E. MOORE: 'Diffusion of Tungsten in Nickel.' *ibid.*, p. 29.
Abstract of paper to American Physical Society, June, 1954.

Diffusion of radioactive tungsten in nickel was measured over the range 1100°C. to 1400°C.

Diffusion in the Copper-Nickel System

W. SEITH and R. LUDWIG: 'Contribution to the Elucidation of Diffusion Processes in the Copper-Nickel System.' *Zeitsch. f. Metallkunde*, 1954, vol. 45, June, pp. 401-7.

The studies reported were carried out with the particular aim of investigating phenomena described by SMIGELSKAS and KIRKENDALL with regard to diffusion of zinc and of copper in alpha brass (*Trans. Amer. Inst. Mining and Metallurgical Engineers*, 1947, vol. 171, pp. 130-5).

Constitution of Nickel-Copper-Aluminium Alloys

F. MAZZOLENI: 'The Hume-Rothery Phases in Systems with more than Two Components. IV. The Ni-Cu-Al_3 System (7 : 4).' *Metallurgia Italiana*, 1954, vol. 46, May, pp. 185-8.

Report of experiments made to confirm the existence of a ternary Hume-Rothery phase with 7 : 4 ratio in the nickel-copper-aluminium system.

Isothermal Transformations in Nickel-Aluminium Bronzes

R. HAYNES: 'Isothermal Transformations of Hypo-Eutectoid Aluminium Bronzes.' *Jnl. Inst. Metals*, 1953–54, vol. 82, June, pp. 493–6; Advance Copy 1546.

The work described was carried out on alloys of the compositions shown below:—

Cu %	Al %	Ni %	Fe %	Si %
88·59	11·40	Nil	0·01	Nil
88·39	10·57	1·02	0·02	trace
86·43	10·54	3·03	trace	Nil

The alloys were isothermally transformed in the range 350°–560°C., and the results are shown as time/temperature/transformation diagrams. The course of the transformations is described and the mechanism of formation of the cellular eutectoid is discussed.

Nickel was found to have but little effect on the rates of transformation, but the presence of 3 per cent. of nickel resulted in formation of a double 'knee' in the curve representing the start of the eutectoid reaction.

On quenching of the high-temperature phase, β, an ordered martensitic phase is formed. In the experiments reported neither a microstructural change associated with an ordering reaction, nor the temperature at which martensite first forms, was detected in the range 560°–350°C.

Constitution of Nickel-Manganese Alloys

V. N. EREMENKO and T. D. SHTEPA: 'The Equilibrium Diagram of the System Manganese-Nickel.' *Ukrain. Khim. Zhur.*, 1952, vol. 18, pp. 219–31.

Range 21·9 to 81·5 per cent. nickel.

See also—

V. N. EREMENKO and V. I. SKURATOVSKAYA: 'The Effect of Addition of Nickel on Polymorphic Changes of Manganese.' *ibid.*, pp. 213–18.

Abstracts of both papers in *Chemical Abstracts*, 1954, vol. 48, pp. 3126 and 3127.

Crystallization Characteristics of Nickel-Carbon Alloys

E. SCHEIL: 'Investigations on the Crystallization of Nickel-Carbon Alloys and of Cast Iron.' *Archiv f.d. Eisenhüttenwesen*, 1954, vol. 25, Jan.-Feb., pp. 71–6.

This paper reports part of a study of the recrystallization characteristics of nickel-carbon alloys, as an analogy with those of cast iron. Due reference is made to the earlier work of MORROGH and WILLIAMS, who also used alloys of this system in connexion with investigation of graphite formation in cast iron (*Jnl. Iron and Steel Inst.*, 1947, vol. 155, pp. 321–71). The present paper covers only the experiments relating to formation of flake graphite: the occurrence of the spheroidal form was dealt with in an earlier communication by SCHEIL and HÜTTIG (*Archiv f.d. Eisenhüttenwesen*, 1953, vol. 24, pp. 237–46).

The work reported leads the author to the conclusion that the graphite in nickel-carbon alloys precipitates directly, *not* (as concluded by MORROGH, *loc. cit.*) by decomposition of a previously formed carbide. The effect of super-heating, which is well known in cast iron, is operative also in the nickel-carbon alloys, but the assumption of silicate nucleation appears to be an unlikely explanation. In pure nickel-carbon alloys under-cooling is followed by a rise in temperature, but when magnesium is present in very small amounts (insufficient to form spheroidal graphite) this rise is not observed.

Determination of the Liquidus Points of Nickel-Titanium Alloys

See abstract on p. 124.

Precipitation-Hardening Copper-Manganese-Nickel Alloys

O. DAHL and K. L. DREYER: 'The Hardenability of Copper-Manganese-Nickel Alloys. I. Investigation of Hardness and Structure.' *Zeitsch. f. Metallkunde*, 1954, vol. 45, June, pp. 342–9.

The authors report a study of precipitation-hardening, as a function of composition, tempering temperature and duration of tempering. It was found that susceptibility to precipitation hardening first occurs at about the 20 per cent. level of NiMn, and that with increasing percentage of these elements there is a marked rise in hardening capacity. Maximum hardening is secured by tempering within the range 400°–450°C., but the increased hardness is associated with severe reduction of ductility. Electrical resistivity falls markedly as the hardness rises. Structures observed in the precipitation-hardened alloys are illustrated. The effects of combined cold-working and tempering were investigated on selected alloys, and over-ageing studies were made as a function of time and temperature of heating.

Precipitation-Hardening Copper-Nickel-Silicon-Aluminium Alloy

D. B. ROACH, R. B. FISCHER and J. H. JACKSON: 'A Precipitation-Hardenable Copper-Nickel-Silicon-Aluminum Alloy.' *Trans. Amer. Soc. Metals*, 1954, vol. 46, pp. 329–45.

This is the full form of the paper referred to from abstract source in *Nickel Bulletin*, 1953, vol. 26, No. 6, p. 94.

Precipitation Phenomena in Hardenable Nickel-Chromium-base Alloys

J. MANENC: 'X-Ray Study of Structural Developments in a Precipitation-Hardenable 80–20 Nickel-Chromium Alloy.' *Comptes Rendus*, 1954, vol. 238, May 3, pp. 1817–19.

After reference to some of the literature on metallographic investigation of precipitation phenomena in

nickel-chromium-base alloys containing aluminium and titanium, the author describes observations made on an alloy of this type tempered at various temperatures after water quenching from 1100°C. X-ray examination showed that, prior to any degree of precipitation which can be detected by the electronic microscope, there is an indication of disturbance of the homogeneity of the solid solution. This is demonstrated by the appearance of blurred but definite 'ghost' lines of a secondary nature, appearing in association with those characteristic of the matrix structure. The intensity and rate of appearance of these 'ghost' lines varies with the conditions of tempering.

Attention is directed to relevant work by DANIEL and LIPSON, who observed unusual X-ray diffraction effects in the alloy Cu_4FeNi_3 while it was in the process of changing from one face-centred cubic structure into two structures (*Proc. Royal Soc.*, Ser. A., 1943, vol. 181, pp. 368–78). Reference is also made to homogeneity 'disturbances' reported by CHEVENARD in a carbon-containing iron-nickel-chromium alloy (*Comptes Rendus*, 1934, vol. 198, p. 1144.)

Properties of Nickel Silvers of Varying Nickel Content

G. R. GOHN, J. P. GUERARD and G. J. HERBERT: 'The Mechanical Properties of Some Nickel Silver Alloy Strip.' Appendix to Report of Amer. Soc. Testing Materials Committee B-5 on Copper and Copper Alloys, Cast and Wrought. *A.S.T.M. Preprint 10*, June 1954, pp. 22–49.

Nickel silver strip has for many years been used as an engineering material in the manufacture of small flat, or formed punched, springs. The 18 per cent. nickel alloy is usually specified for such applications, due to its good mechanical properties, ease of fabrication, and pleasing appearance, but conditions during the war and post-war periods have intensified interest in nickel-copper-zinc alloys of lower nickel contents. Preliminary studies of various alloys indicated that the 12 per cent. nickel type would provide the properties requisite, and in 1946 it was incorporated in A.S.T.M. specification B-122.

With a view to exploring more exhaustively the potential usefulness of this and other grades, a detailed examination has now been made of the properties of four types of nickel silver:—

(1) The standard 18 per cent. grade, containing copper 55, zinc 27, per cent.
(2) Nickel 12, copper 56·5, zinc 31·5, per cent.
(3) Nickel 12, copper 60, zinc 28, per cent.
(4) Nickel 10, copper 60, zinc 30, per cent.

Details are given of typical compositions of alloys studied as representative of the respective grades.

The results of tensile tests, made by standard methods on strip of all the alloys in various tempers, are shown in an extensive series of tables and graphs, and reversed-bend fatigue data are also reported. The conclusion drawn is that the standard 12 per cent. nickel alloy (No. 2 above) has mechanical properties comparable with those of the 18 per cent. nickel grade and that the 12 per cent. alloy is suitable for spring applications. The only significant difference in mechanical properties between the two alloys is the slightly lower modulus of elasticity of the 12 per cent. nickel grade, which indicates that where the rate of build-up is critical it may be necessary to use slightly heavier stock in order to obtain comparable load-deflection characteristics. The data obtained with No. 3 alloy (copper 60 per cent.) lead to the conclusion that the increase in copper content has no deleterious effect on mechanical properties. The 10 per cent. nickel alloy shows fatigue characteristics comparable with those of the 12 and 18 per cent. nickel grades, but its lower elastic properties would preclude its use in spring applications.

Creep Properties of Copper-Nickel Alloys

See abstract on p. 144.

Permanent-Magnet Materials: Evaluation of Types Currently Available

See abstract on p. 134.

Nickel-Chromium-Boron Alloy Facing for Wear- and Corrosion-Resistance

See abstract on p. 149.

Nickel-Tin Bronze: A.S.T.M. Specification

AMER. SOC. TESTING MATERIALS, COMMITTEE B-5 ON COPPER AND COPPER ALLOYS: 'Proposed Tentative Specifications for Nickel-Tin Bronze Castings.' Contained in *A.S.T.M. Preprint 10*, June, 1954, pp. 18–21.

The Committee has proposed, for adoption as tentative, a specification covering castings in two alloys, the classifications and compositions of which are shown below:—

	Alloy A (Heat-treatable)		Alloy B (Leaded)	
	Min.	Max.	Min.	Max.
Copper % ..	85·0	90·0	84·0	89·0
Tin % ..	4·5	6·0	4·5	6·0
Nickel % ..	4·5	6·0	4·5	6·0
Lead % ..	—	0·10(a)	—	1·0
Zinc % ..	—	2·5	—	2·5
Impurities:				
Iron % ..	—	0·25	—	0·25
Manganese %	—	0·20	—	0·20
Antimony %	—	0·15	—	0·15
Others % ..	—	0·25	—	0·25

(a) The mechanical properties of alloy A in the heat-treated condition may not be attained if the lead content exceeds 0·01%.

	Tensile Strength min.		Yield Strength min.		Elongation in 2 in., min.
	p.s.i.	t.s.i.*	p.s.i.	t.s.i.*	%
Nickel–Tin Bronze—					
As cast—alloy A	45,000	20·0	20,000	10·0	25
Heat treated—alloy A ..	75,000	33·5	50,000	22·5	5
Leaded—as cast—alloy B ..	40,000	18·0	20,000	10·0	20

* To nearest half ton.

Tensile requirements are as in the Table above.

Castings of alloy A, heat-treated to high strength and hardness, may be used for constructional or pressure purposes, e.g., in machinery, frames, gears, cams, switchgear, electric-line hardware, bushings, pumps, valves and cylinders.

Monel Equipment in Fluorine-Disposal Plant

See abstract on p. 155.

Nickel-containing Spring Alloys

See abstract on p. 135.

Soil-Corrosion Tests on Bolt Materials

See abstract on p. 156.

Chemical Brightening of Brass and Nickel Silver

G. SCHMID and H. SPAHN: 'The Chemical Brightening of Brass and Nickel Silver.'

'I. The Composition of the Bath.' *Zeitsch. f. Metallkunde*, 1954, vol. 45, June, pp. 392–7.

This is the first of a series of papers which will report a systematic investigation of the influence of operating variables, on chemical brightening of copper alloys in solutions based essentially on the types recommended in U.S. Patent 2,446,060, granted in 1950 to Batelle Memorial Institute. This patent specifies mixtures of nitric, phosphoric and acetic acids, but the preferred ratio of the three acids is not clearly defined. The present authors have therefore made a study of the effect of variations in the proportions.

Three types of ternary mixture were investigated:—(1) nitric acid-phosphoric acid-acetic anhydride; (2) nitric acid- sulphuric acid- acetic acid; and (3) nitric acid- phosphoric acid-water. The influence of temperature of the solutions (20°, 40° and 60°C.) was also studied. The materials used were rolled sheet of brass (63–37 copper-zinc type), and nickel silver (copper 60, nickel 18, zinc 22, per cent.). The results are shown in diagrams indicating the surface condition (eight stages, from mirror to dull) produced by immersion in the respective solutions, under varying conditions of temperature and ratio of constituent elements in the baths.

'II. The Microstructure of the Surface of the Chemically Brightened Alloys.' *ibid.*, pp. 398–401.

The surface condition of the treated alloys was microscopically examined and was compared with that of unpolished and mechanically polished surfaces of similar materials. The results indicate that chemical brightening smooths out micro-roughnesses of the order of 1μ, whereas irregularities of larger size are frequently accentuated by the chemical treatment. Brightness which is perceptible to the naked eye is apparently but little vitiated by such irregularities.

Electrolytic Polishing of Metals and Alloys: Reference Data

See abstract on p. 124.

Gas-Shielded Arc Processes for Cutting Nickel and Its Alloys

W. G. HULL: 'Use of Gas-Shielded Arc Processes for Cutting Non-Ferrous Metals.'

Welding and Metal Fabrication, 1954, vol. 22, May, pp. 188–91.

Details are given of experiments made, under the aegis of the British Welding Research Association, in which the argon-arc and self-adjusting arc processes were used for cutting some materials which are not amenable to oxygen-cutting. The following materials were among those used in the argon-arc cutting tests: nickel plate ($\frac{3}{16}$ and $\frac{1}{2}$ in. thickness), Nimonic 75 plate ($\frac{1}{2}$ in.), Monel plate ($\frac{1}{8}$ and $\frac{1}{2}$ in.) and Inconel wire (12 s.w.g.). The tests made by the self-adjusting arc process were on aluminium alloys only. The author emphasizes that the results are to be regarded as merely an exploration of the potentialities of the processes as practical methods of cutting: on the basis of the results obtained in such preliminary work he makes the following comments:—

'Promising results were obtained with 1-in. aluminium–5 per cent. magnesium and $\frac{5}{16}$-in. thick copper plate, the edges of the cuts being straight and of even width. Although it was possible to cut the various nickel-base materials, the appearance of the kerf was less satisfactory. With these materials the edges were more irregular, the worst case being Monel, where considerable exudation also occurred from the edges as cutting proceeded. Residual fused material was generally present at the edges of the cuts, but with aluminium, copper and certain of the nickel alloys the depth of fusion was negligible, and in practice could be quickly removed if necessary by a simple machining operation.

'It is clear that argon-arc cutting depends solely

upon the melting away of material by the heat input from the arc and in this respect is similar to other arc cutting methods, e.g., carbon-arc. Due to the dimensions of the arc, melting occurs over an appreciable area, forming relatively wide cuts. There is also a tendency, which is more marked with the nickel-base alloys, for a relatively large molten pool to be built up before removal under gravity occurs. As the metal is removed intermittently during cutting, irregularities at the edge are produced.

'Although it is probable that, with further work on the argon-arc method, techniques could be developed which would produce cuts of improved surface characteristics, it is felt that the self-adjusting arc process has certain features which make it the more adaptable of the two processes as a method of cutting. In the latter process the arc originates from a consumable electrode of small diameter, e.g., $\frac{1}{16}$ in., operating at very high current densities. A narrow heat source of high intensity is, therefore, applied to the plate, and cuts can be produced which are appreciably narrower than those obtained by the tungsten arc. Cutting speeds are also considerably higher. The process is normally operated from a D.C. power source with electrode positive, this electrode arrangement providing an effective oxide cleaning action on the work pieces. Although it is irresolvable by eye, it is probable that, during cutting, the terminal portion of the electrode moves progressively from the top surface of the plate to the bottom and *vice versa*. Due to the high current densities employed, the material is transferred at high velocity across the arc column, as extremely small globules. It is thought that this 'spray' type of metal transfer, in conjunction with the possible cyclic movement of the anode mentioned above, assists the cutting action by rapidly dispersing molten material as it is formed at the leading edge of the cut. The arc also exhibits mechanical stiffness, being held in line with the electrode by surrounding magnetic fields of high intensity, and, as a result, positional cutting is possible, as was shown in the manual tests carried out on aluminium-magnesium alloy plate. The tests carried out suggest the possible use of the process as a method of preparing plate edges for welding, and it is felt that, with a more detailed knowledge of the effect of the various factors mentioned earlier, suitable techniques might be developed.'

Joining of Tubes to Tube Sheets: Procedures Suitable for Various Materials

See abstract on p. 141.

NICKEL-IRON ALLOYS

Permanent-Magnet Materials: Evaluation of Types Currently Available

C. A. MAYNARD: 'Selection of Permanent-Magnet Materials.' *Electrical Manufacturing*, 1954, vol. 53, Jan., pp. 114–19.

This article gives a summary of the properties of nineteen types of permanent-magnet material, including eleven grades of Alnico (nickel-aluminium-cobalt-iron base); Cunife (copper-nickel-iron); Cunico (copper-nickel-cobalt); Indox ('ferrite' type); chromium steel; high-cobalt steel; Indalloy (iron-cobalt-molybdenum); and Remalloy* (cobalt- molybdenum-iron).

These materials are evaluated on the basis of (1) twelve magnetic characteristics which affect the suitability of permanent-magnet materials for specific applications, (2) factors relating to application and design, (3) the mechanical and physical properties of the materials and their relative cost of processing, and (4) their capability of being produced in service form by normal manufacturing methods, and their limitations as to shape producible.

Magnetic Viscosity in Nickel-Aluminium-Iron Alloys

J. H. PHILLIPS, R. STREET and J. C. WOOLLEY: 'Magnetic Viscosity in Precipitation Alloys: FeNiAl, Fe_2NiAl and Alnico.' *Philosophical Magazine*, 7th Ser., 1954, vol. 45, May, pp. 505–23.

The paper reports experiments made to determine the effects of various heat-treatments on magnetic viscosity in alloys of FeNiAl and Fe_2NiAl compositions and in a typical permanent-magnet alloy (based on Fe_2NiAl), the approximate composition of which was iron 54, aluminium 10, nickel 18, cobalt 12, copper 6, wt. per cent.

The heat-treatments used were (*a*) quenching at various rates, from the solution temperature; (*b*) annealing of water-quenched specimens at various temperatures in ranges in which precipitation takes place, and (*c*) annealing of specimens which had been cooled at various rates from the solution temperature. The results are interpreted in terms of the thermal-activation theory of magnetic viscosity, Néel's disperse field theory, and Geisler's theory of coherency hardening. It is shown that magnetic viscosity methods can be applied to investigate precipitate and magnetic structures of the order 10^{-17} cm^3 in volume, which are below the limit of resolution of more conventional techniques. Specimens of Alnico and Fe_2NiAl were suitably treated to enable magnetic viscosity measurements to be made at temperatures up to 900°K. (627°C.) The results obtained, together with others previously reported, show that the thermal-activation theory is valid at least over the temperature range 90°K. (−183°C.) to 900°K. (627°C.) The variation of the coercive force of these alloys as a function of temperature is also considered.

Nickel-Iron Temperature-Compensating Alloys

W. S. EBERLY: 'Temperature-Compensator Alloys.' *Machine Design*, 1954, vol. 26, May, pp. 152–6.

Many types of equipment and instruments are called upon to operate within a relatively wide range of ambient temperatures, e.g., from about −70° to +250°F. (−55° to + 120°C.). Variations of this order present a serious problem in installations in which there are temperature-sensitive elements such as permanent magnets, drag discs, resistances, etc. In this

* A type also known as Comol.

connexion magnetic shunts composed of thermo-magnetic alloys play an important part: typical applications include compensatory control in watt-hour meters, tachometers, automobile speedometers, and voltage regulators for automotive and aircraft use.

The author of this article discusses the nature of the disturbance introduced by change of temperature in performance of various parts of such equipment and describes the characteristics of temperature-compensator alloys which may be used as controls. The most commonly employed are the iron-nickel alloys containing nickel from about 28·5 to 33 per cent. The influence of nickel content within this range, on the permeability-temperature properties of the alloys, is graphically shown and the utilization of these properties in single and compound magnetic shunts is described in relation to typical applications.

Nickel-containing Spring Alloys

B. COATES: 'Properties of Light Springs.' *Metal Treatment*, 1954, vol. 21, June, pp. 284–8.

The requirements which must be met in a material suitable for spring manufacture are critically considered; defects and faults which may occur in springs are discussed, and the significance of the fatigue factor, as affecting spring life, is emphasized. The compositions and properties of steels used for springs are then tabulated, and non-ferrous spring alloys are reviewed. In this connexion attention is directed to aluminium-base alloys, beryllium-copper, complex nickel-iron alloys of the Elinvar type, precipitation-hardening iron-nickel-titanium alloys, alloys of the Nimonic series, constant-modulus alloys such as Nispan C (nickel-iron-chromium-titanium), Monel and its age-hardening modification, K Monel, and the nickel-chromium-iron alloy Inconel. The scope of application of the respective types is broadly indicated.

CAST IRON

Notch Ductility of Spheroidal-Graphite Cast Iron

W. S. PELLINI, G. SANDOZ and H. F. BISHOP: 'Notch Ductility of Nodular Iron.' *Trans. Amer. Soc. Metals*, 1954, vol. 46, pp. 418–45.

This paper describes research carried out at the Naval Research Laboratory, Washington, D.C., on the shock-resistance of S.G. iron. The results have led to the acceptance, in the U.S.A., of S.G. iron for shipboard castings, under specification MIL-I-17166A (Ships).

Tests were made on induction-furnace melts covering a wide range of composition, involving variations in carbon, silicon, manganese, nickel, copper, and phosphorus contents. Other factors studied included the amount of retained pearlite and the influence of section-size. Data on tensile, yield, and elongation properties are quoted for each series of irons.

V-notched Charpy tests were made on all the materials, in each case over a wide temperature range: transition characteristics were studied with respect to energy absorption, appearance of fracture, and notch ductility, and the results of the tests are compared with corresponding data for rolled and cast steel. Supplementary tests were made with the specific object of comparing the influence of sharpness of the notch on mode of failure. Other shock tests (by drop-weight and explosion in a confined space) were also carried out.

In discussing the results of the whole series of tests, the authors draw attention to the surprisingly good behaviour of S.G. iron, and comment on the observation made (in photomicrographic studies of the specimens after test) that cracks in the S.G. iron were frequently found to terminate in spheroid cavities, necessitating initiation of a new crack at the opposite side of the cavity before failure could continue. The principal conclusions drawn by the authors are quoted below:—

'Charpy V transition data indicate that fully ferritized material is required for optimum notch toughness; also that silicon and phosphorus contents should be held to the lowest practical limits. Normal variations of manganese, nickel or copper do not appear to have significant effects.

'The Charpy V transition ranges of low-silicon and -phosphorus (lower than normal commercial practice) ferritized nodular irons are equivalent to those of average-quality cast and rolled mild steels; however, the maximum energy levels developed at the upper shelf of the transition curves are markedly lower than those of the steels.

'Impact and explosion tests of the various types of nodular irons demonstrate the same relative resistance to brittle fracture as indicated by Charpy tests. High silicon and phosphorus contents and incomplete ferritization are demonstrated to be embrittling factors.

'Brittle fractures are developed in the explosion tests only at temperatures corresponding to the transition range of the Charpy energy curve. Shear fractures are developed at temperatures corresponding to the upper shelf of the transition curve. This information in effect calibrates the significance of Charpy V transition curves for nodular iron, and demonstrates that the low levels of energy are not *per se* indicative that the material will behave in a brittle fashion in service.

'Impact and explosion tests of castings indicate that fully ferritized nodular irons of normal silicon and phosphorus contents (2·75–3·50 per cent. silicon and approximately 0·05 per cent. phosphorus) are less resistant to brittle fracture than average-quality cast and rolled mild steels. When the silicon and phosphorus contents are lowered to approximately 2·0 and 0·01 per cent., respectively, equivalent fracture-resistance is attained.

'The excellent resistance to fracture of nodular irons, despite the known brittleness of the high-silicon ferrite matrix, is ascribed to the presence of the graphite spherulites. For the same matrix composition the material is changed from ductile to highly brittle by removing the graphite spherulites.

'Explosion tests of castings free from notch defects show that nodular iron is capable of withstanding drastic deformation prior to fracture. As in the case of steels, sharp notches are required to promote the

initiation of brittle fractures at normal service temperatures and for conventional loading conditions which do not entail plastic deformation.'

U.S. Specifications for S.G. Iron

SOC. AUTOMOTIVE ENGINEERS:
'Ductile Iron Castings (Nodular) 60,000 p.s.i. Tensile *A.M.S. Specn. 5315.*'
'Ductile Iron Castings (Nodular) 80,000 p.s.i. Tensile *A.M.S. Specn. 5316.*'

The specifications include the usual clauses covering inspection and acceptance of the castings. The composition (common to both specifications) is within the following limits: carbon 3·2–4·0, manganese 0·8 max., silicon 1·7–2·5, phosphorus 0·08 max., per cent. It is permitted that silicon shall be as high as 2·8 per cent. if phosphorus is not above 0·05 per cent. A.M.S. 5315 covers castings in the annealed condition: A.M.S. 5316 relates to as-cast, normalized, or normalized and tempered material.

The following requirements are laid down:—

Tensile Test Specimens

Standard tensile test specimens (0·357-in. diameter at the reduced parallel section from ½-in. Y block; 0·505-in. diameter at the reduced parallel section from other tensile test coupons). Properties required are shown in Table I.

Alternatively, when the tensile properties of actual castings are determined for acceptance, the properties of specimens cut from sections of castings are as specified in Table II.

Microstructure

A.M.S. 5315.—Spheroidal graphite in a matrix of ferrite with few areas of pearlite allowed: essentially free from flake graphite and carbide.

A.M.S. 5316.—Spheroidal graphite in a matrix of ferrite and fine pearlite: essentially free from flake graphite and carbide.

Impact and Resilience Properties of Cast Irons

G. N. J. GILBERT: 'The Impact Properties of Flake-Graphite Cast Irons.' *Brit. Cast Iron ResearchAssocn., Jnl. of Research and Development*, 1954, vol. 5, June, pp. 298–317: Research Rept. 384.

This paper reports tests in which resilience (as measured by a slow-bend test) was correlated with Charpy impact value, in a series of eight cast irons of varying composition and structure. The range studied included five unalloyed irons, two acicular irons containing small amounts of nickel and molybdenum, and an austenitic iron (nickel 16·5, chromium 1·62, copper 7·48, per cent.).

The results indicate that the impact value usually places the cast irons in the order of their resilience, but that it does not provide an absolute value for

Table I

	A.M.S. 5315			A.M.S. 5316		
	p.s.i.	t.s.i.	kg/mm²	p.s.i.	t.s.i.	kg/mm²
Tensile Strength, min. ..	60,000	26·8	42·2	80,000	35·75	56·3
Yield Strength at 0·2 per cent. offset in 2 in. extension under load, min. ..	45,000	20·0	31·5	60,000	26·8	42·2
Elongation, % in 4D ..	15% min.			3% min.		

Table II

	A.M.S. 5315			A.M.S. 5316		
	p.s.i.	t.s.i.	kg/mm²	p.s.i.	t.s.i.	kg/mm²
Tensile Strength, min. ..	60,000	26·8	42·2	80,000	35·75	56·3
Yield Strength at 0·2 per cent. offset in 2 in. extension under load, min. ..	45,000	20·0	31·5	60,000	26·8	42·2
Elongation, % in 4D ..	10% min.			2% min.		
Hardness .. .. .. (Castings and test coupons)	Less than 190 B.H.N.			202–269 B.H.N.		

resilience. It was observed that as the size of a specimen is increased resilience is increased by a factor which varies between the square and the cube of the increase in size. Tests at various temperatures show the existence of a transition-temperature range in cast irons.

Crystallization Characteristics of Nickel-Carbon Alloys and Cast Iron

See abstract on p. 131.

Welding of S.G. Iron

F. A. BALL and D. R. THORNEYCROFT: 'Metallic-Arc Welding of Spheroidal-Graphite Cast Iron.' *Inst. Brit. Foundrymen, Advance Copy* 1095, June, 1954; 16 pp.

S.G. iron has many potential applications in which individual castings may form part of a larger structure fabricated by welding. In such cases it is desirable that the strength and ductility of the welded joints shall be closely equivalent to those of the parent material. Although various welding techniques for S.G. iron are now under review, present indications are that the metallic-arc method is most likely to give satisfactory results. The authors of this paper report a detailed study of this technique, using nickel-iron electrodes of a type which is already in commercial supply and is being successfully used. A full account is given of the mechanical properties, structure, and machinability of welds made by this process. Some trials were also made with an aluminium-bronze electrode. These were only partially successful, but it may be anticipated that further attention will be given to development of the potential usefulness of 'bronze welding', with other types of electrode.

Soil-Corrosion Tests on Bolt Materials

See abstract on p. 156.

CONSTRUCTIONAL STEELS

Low-Alloy High-Tensile Steels: Literature Review

'Literature Survey of High-Strength Steels.' *Welding Jnl.*, 1954, vol. 33, May, pp. 251S–6S.

In connexion with the revision of specifications for pressure-vessel steels, a Committee of the Welding Research Council is investigating the suitability of low-alloy high-tensile steels for such purposes. The first undertaking of the Committee has been a survey of the literature on steels falling within this category. This report summarizes available information.

The results of the survey are presented in tabular form, showing trade names of such steels, manufacturers, and mechanical properties, together with some information on fatigue strength and welding characteristics. Over 100 steels are listed, including American, British, German, Austrian, French and Italian types.

Softening of Cold-Worked Metals under Fatigue Conditions

See abstract on p. 124.

Influence of Composition on Transverse Mechanical Properties of Steels

C. WELLS, J. V. RUSSELL and S. W. POOLE: 'Effect of Composition on Transverse Mechanical Properties of Steel.' *Trans. Amer. Soc. Metals*, 1954, vol. 46, pp. 129–56.

This report is one of a series resulting from an extensive programme of work at the Carnegie Institute of Technology, where a study is being made of variables in steelmaking practice and heat-treatment as affecting ductility and toughness in heat-treated wrought steel products. (Reference is given, in the *bibliography*, to earlier reports on other aspects of the investigation.)

In the work covered by this paper eleven electric-furnace production heats were used, representative of base compositions generally employed for alloy steels. The composition of a series of ingots from each of these heats was modified by controlled ingot-mould additions of carbon, silicon, nickel, chromium, molybdenum, boron, and rare earths. The hot-rolled or forged ingot product (usually in the form of 1-in. thick sections cut from a 7-in. diameter round) was quenched and tempered to various levels of tensile strength, in order to evaluate (*a*) the effect of carbon, (*b*) the effects of silicon, nickel,chromium, and molybdenum, (*c*) the effects of boron added in various forms, (*d*) the effects of rare-earth metals added as metals or oxides, and (*e*) the effects of combinations of boron, rare earths and silicon. The basis of evaluation was the effect of the respective modifications in composition on transverse tensile strength, transverse reduction of area, and transverse impact-resistance. The results (to be considered as preliminary) are presented as a comparison of the properties named, as they would be expected to occur at identical strengths in the range 150,000–185,000 p.s.i. (67–82·5 tons per sq. in.).

A general outline of the conclusions is given below:—

For a given tempering temperature increase in carbon (0·1–0·5 per cent.) resulted in roughly linear increase in tensile strength in the quenched and tempered steels: with the higher tempering temperatures the increase was somewhat less than for those in the lower range. For a given tensile level (185,000 p.s.i.; 82·5 tons per sq. in.) increasing the carbon content over the range 0·33 to 0·51 per cent. lowered the transverse reduction of area by about 1·5 per cent. for each 0·1 per cent. of carbon. For the same range of carbon the transverse impact quality at 172,000 p.s.i. (77 tons per sq. in.) tensile level was lowered at 70°F. (21°C.) by about 2·5 ft.-lb. per 0·1 per cent. carbon. At lower temperatures of test the influence of carbon on impact was less pronounced.

Additions of chromium, molybdenum, vanadium and silicon conferred greater strength on steels tempered at a given temperature, due to the increased resistance to tempering resulting from the presence of these elements. Added nickel had practically no effect on resistance to tempering. In fully hardened steels increase in chromium, molybdenum, vanadium, and nickel had no significant effect on transverse reduction of area or transverse impact-resistance. Increased silicon lowered transverse ductility, but did

not significantly affect transverse toughness, except in steels tempered at high temperatures. The authors draw particular attention to the influence of nickel in improving transverse impact quality in slack-quenched steels; the improvement was due mainly to the lowering of the transition temperature resulting from the nickel addition.

Additions of boron increased tensile strength only when the corresponding boron-free steel had insufficient hardenability in the section treated. In most cases boron exerted a slightly detrimental effect on transverse reduction of area, except when the basis steel had insufficient hardenability, in which cases the boron improved all properties by increasing the percentage of tempered martensite present after heat-treatment. When hardenability of the boron-free steel was adequate the boron addition somewhat lowered the transverse impact values.

Addition of rare-earth metals, *per se*, did not affect hardenability or tensile strength, but where transverse ductility and toughness of the base material were below that which would be expected in a given steel of good quality, the rare-earth metal additions usually improved these properties up to the level to be anticipated for a satisfactory grade of the unmodified steel. The overall effect of adding boron and rare-earth metals to the steels studied is considered to be a net gain in hardenability and mechanical properties. Rare-earth oxides in boron-treated steels lowered both transverse ductility and toughness. In steels other than those treated with boron, rare-earth oxides did not significantly affect hardenability, tensile strength, transverse ductility, or transverse toughness.

Elevated-Temperature Short- and Long-Time Tests on Low-Nickel Alloy Steels

G. V. SMITH and W. B. SEENS: 'Short-Time Tension and Creep-Rupture Properties of Hardened 1040, 4340, and Ni-Cr-Mo-V Steels up to 1000°C.' *Amer. Soc. Testing Materials, Preprint 78*, June 1954; 10 pp.

Following work by the authors, some years ago, on the properties of nickel-chromium-molybdenum and nickel-chromium-molybdenum-vanadium steels at temperatures up to 700°F. (370°C.), interest in the use of such steels at higher temperatures became evident. This later paper reports an investigation of properties up to 1000°F. (538°C.) of the same steels, heat-treated to a tensile strength of 150,000 p.s.i. (67 tons per sq. in.). The composition of the materials used is shown in Table I below.

The 1040 steel was included in the tests on account of its freedom from 'strategic' elements, but this steel is not comparable in hardenability with the two alloy grades and would therefore be suitable for use only in very thin sections.

All the steels were tested in creep-rupture at 850° and 1000°F. (454° and 538°C.), and since the 1040 steel had not been previously examined it was tested also at 500° and 700°F. (260° and 370°C.). Short-time tensile tests were made, on all the steels, at 80°, 500°, 700°, 850° and 1000°F. (27°, 260°, 370°, 454° and 538°C.).

As a basis for comparison of the three materials, stresses for rupture in 1000 hours and for a minimum creep rate of 0·01 per cent. per hour are shown: see Table II on p. 139.

In the short-time tests the yield and tensile strengths of all three steels decreased with rise in temperature (except for a slight intermediate rise at 500°F. (260°C.) in the tensile strength of the 1040 steel, which is thought to have been due to strain-ageing). At the same time, elongation and reduction in area increased. The nickel-chromium-molybdenum and nickel-chromium-molybdenum-vanadium steels retained their strength to approximately the same degree as the temperature of test was raised, but at 850° and 1000°F. (454° and 538°C.) the 1040 steel was significantly weaker, and in the creep-rupture tests (see table) its inferiority was even more clearly marked. At 850° and 1000°F. (454° and 538°C.) the properties of the vanadium-containing steel were better than those of the nickel-chromium-molybdenum 4340 type. All three steels showed good ductility in the creep-rupture tests. The higher the temperature of test and the longer the period of test, the more pronounced was the tendency to carbide spheroidization. Fractures appeared to be transgranular at all test temperatures, but under the longest times and highest temperature conditions there was a trend towards a more intergranular form.

Table I
Chemical Composition and Heat-Treatment of Test Steels

Grade	C	Si	Mn	S	P	Ni	Cr	Mo	V	Austenitizing Temperature (a)		Tempering Temperature (b)	
	%	%	%	%	%	%	%	%	%	°F.	°C.	°F.	°C.
1040	0·41	0·22	0·77	0·035	0·018	—	—	—	—	1550	845	840	450
4340	0·39	0·29	0·71	0·016	0·012	1·82	0·72	0·28	—	1550	845	1170	630
Ni-Cr-Mo-V ..	0·40	0·15	0·21	0·015	0·015	2·0	0·97	0·37	0·18	1600	870	1245	675

(a) 1 hr. at temperature.
(b) 2 hrs. at temperature.

Table II
Results of Creep-Rupture Tests

Grade	Stress for Rupture in 1000 hrs.							
	500°F. (260°C.)		700°F. (370°C.)		850°F. (454°C.)		1000°F. (538°C.)	
	p.s.i.	t.s.i.	p.s.i.	t.s.i.	p.s.i.	t.s.i.	p.s.i.	t.s.i.
1040	108,000	48·25	56,000	25·0	21,500	9·5	6,400	2·9
4340	—	—	—	—	65,000	29·0	16,300	7·25
Ni-Cr-Mo-V ..	—	—	—	—	80,000	35·7	23,500	10·5
Grade	Stress for Minimum Creep Rate of 0·01 per cent. per hr.							
	500°F. (260°C.)		700°F. (370°C.)		850 F. (454°C.)		1000°F. (538°C.)	
	p.s.i.	t.s.i.	p.s.i.	t.s.i.	p.s.i.	t.s.i.	p.s.i.	t.s.i.
1040	—	—	55,000	24 5	18,500	8·25	5,200	2·3
4340	—	—	—	—	65,000	29·0	18,000	8·0
Ni-Cr-Mo-V ..	—	—	—	—	80,000	35·7	29,000	13·0

Structural Stability and Creep-Resistance of Plain and Low-Alloy Steels

A. B. WILDER, E. F. KETTERER and D. B. COLLYER: 'Creep Rupture Properties and Structural Changes in Carbon and Low-Alloy Steels.' *Jnl. of Metals*, 1954, vol. 6, June; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 764–72.

In connexion with the increasingly exacting requirements imposed on seamless piping used in various elevated-temperature applications, it has become necessary to develop a more exact knowledge of the properties of steels used for such purposes. To this end, an examination has been made of the microstructural stability of 59 carbon and low-alloy steels, after exposures of 34,000 hours at 900° and 1050°F. (480° and 565°C.). The influence of such exposure on the weld heat-affected zone of the steels was also investigated. The report contains also the results of tensile and creep-rupture tests on the parent steels, before and after 10,000 hours' at the same two temperatures. The steels studied include (in addition to various grades of carbon steel) low-alloy types containing chromium+molybdenum, molybdenum+vanadium, chromium+molybdenum with high phosphorus, molybdenum+titanium, molybdenum+niobium; nickel + copper + titanium, nickel + molybdenum + titanium, and molybdenum + copper + titanium.

Heat-Treatment of Case-Hardening Nickel-Alloy Steels

H. KIESSLER and E. KUNZE: 'Influence of Dimensions and of Hardening Temperature on the Hardness and Toughness of Case-Hardening Steels.' *Stahl und Eisen*, 1954, vol. 74, June 3, pp. 768–72.

Report of work carried out, on typical case-hardening steels, in connexion with proposed revision of D.I.N. specification 17 210 and modifications of Stahl-Eisen Prüfblatt 1660-50. Frequency curves, derived from a large number of tests, indicate the effect of the variables mentioned, on hardness and on impact-resistance. The steels used for the tests were two chromium-manganese and three low-alloy nickel-chromium steels. The data presented demonstrate the greater toughness of the nickel-containing steels in comparison with that of the chromium-manganese types.

Nickel-Molybdenum Die Steels

R. B. CORBETT, J. A. SUCCOP and A. FEDUSKA: 'Alpha-Molybdenum Hot-Work Die Steels.'
Trans. Amer. Soc. Metals, 1954, vol. 46, pp. 1599-618; disc., p. 1618.

Resistance to heat-checking, in molybdenum steels used for permanent moulds in centrifugal casting, led to the consideration of such steels as materials for hot-working dies. In experiments with steels containing molybdenum 3·20, carbon 0·15, per cent., it was found that the impact properties were lower than is desirable in such an application, and in order to improve the quality of the steel in this respect the influence of a nickel addition, combined with lowered carbon content, was investigated. This paper reports a study of the characteristics of steels of the compositions shown in the Table on p. 140.

A study of the isothermal-transformation diagrams for the three steels confirmed that the nickel-containing grade was likely to be suitable for manufacture of large die blocks, and the impact and tempering properties for several transformation products were determined for this steel.

The properties of die blocks made from these steels were determined after several tempering treatments. Treatment under certain conditions increased the hardness of the blocks throughout the cross section, as a result of ageing. In impact tests the steel containing

C %	Si %	Mn %	S %	P %	Ni %	Mo %
0·22	0·30	0·50	0·026	0·016	2·80	2·95
0·24	0·30	0·63	0·027	0·016	—	2·95
0·10	0·26	0·50	0·025	0·017	—	2·95

carbon 0·20, nickel 3, molybdenum 3, per cent. showed the best properties, and the superiority of this steel for die blocks was confirmed by results of service tests comprising press and upsetter forging operations. Using blocks made from this steel, increase in production was obtained due to progressive ageing of the die-block surface during use, and the resistance of the steel to heat-checking and consequent premature failure. Advantage can be taken of the age-hardening capacity of the steel by tempering at a temperature below that which produces maximum age-hardness, and putting the dies into service in that condition. Contact with the hot-forging stock causes further progressive hardening of the steel to a limited depth, with associated increase in wear-resistance.

Electrolytic Polishing of Metals and Alloys: Reference Data

See abstract on p. 124.

Design and Materials for Gudgeon Pins

'Gudgeon Pin Design. Some Aspects of the Design of One of the Most Severely Loaded Components in Reciprocating Type Internal Combustion Engines.' *Automobile Engineer*, 1954, vol. 44, June, pp. 251-5.

The article emphasizes the importance of correct design and material for gudgeon pins, which operate at temperatures of the order of 150°C., and are heavily loaded by the combustion pressures and by inertia. In many instances also they are only sparsely lubricated, and the relative motion between the pin and its bearings is of an oscillatory type.

The first section of the article is concerned with materials for the pins, the selection of which varies according to the nature of the service envisaged. In general, En 32 carbon case-hardening steel is considered adequate for petrol engines in private cars and light commercial vehicles. For more highly rated petrol engines, and for Diesels, En 36V (65-ton 3 per cent. nickel-chromium case-hardening steel) or En 354 (1¾ per cent. nickel-chromium-molybdenum case-hardening grade) is favoured by most manufacturers. In very highly rated engines, for racing, and for some aircraft, high-tensile steel to En 39 (4½ per cent. nickel-chromium or nickel-chromium-molybdenum case-hardening type) is preferred, since it permits the use of thinner sections, thus reducing reciprocating weight. The use of S.G. iron for some types of gudgeon pin is also under consideration, and chromium plating of pins, to reduce wear, has given promising results. This article gives some account of heat-treatments applied to the respective steels and of machining and finishing involved in gudgeon pin production.

The major portion of the article is devoted to consideration of design and operating conditions: this section is illustrated by numerous drawings showing recommended forms of pins and the components with which the pins are in contact, and demonstrating effects observed in connexion with pin failures.

Soil-Corrosion Tests on Bolt Materials

See abstract on p. 156.

Standard Methods for Analysis of Iron and Steel

BRIT. STANDARDS INSTN.: 'Methods for the Analysis of Iron and Steel.'

B.S. 1121, Part 13: 'Chromium in Iron and Steel.'

This standard covers a revised method which has been developed as part of a programme of standardization of methods for determination of elements in ferrous materials. Its scope includes the chromium range which had previously been dealt with under *B.S. 1121: Part 8, which schedule is now withdrawn.*

In the revised method a solution of the sample in phosphoric-sulphuric acid is oxidized with ammonium persulphate in the presence of silver nitrate, which acts as a catalyst. The development of a pink colour, due to the oxidation, to permanganic acid, of the manganese in the steel, serves to indicate when the oxidation is complete. If the steel contains little or no manganese it is necessary to add a small amount of this element before the oxidation is begun. The permanganic acid is reduced with hydrochloric acid and the chromium present in the oxidized condition is then titrated, using standard ferrous ammonium sulphate and potassium permanganate.

The range of chromium to which the procedure is applicable is up to 25 per cent., with reproducibility varying according to the amount of chromium present. Recommendations are made with regard to solutions required, analytical technique, and minor modifications in procedure desirable when analyzing individual types of steel.

B.S. 1121, Part 30: 'Cobalt in Iron and Steel.'

The addition of nitroso-R-salt (sodium-1-nitroso-2-naphthol-3: 6-disulphonate) to a neutral or buffered solution containing cobalt is used to produce a reddish-brown colour, which is proportional to the amount of cobalt present. Interfering complexes of other metals are destroyed by the addition of nitric acid, followed by a short period of standing. The

range of the method is up to 12 per cent. of cobalt, and it has proved satisfactory in analysis of a wide variety of alloy steels. The schedule gives full details of analytical solutions and procedure.

Determination of Sulphur in Steels by the Combustion Method

BRIT. IRON AND STEEL RESEARCH ASSOCN. METHODS OF ANALYSIS COMMITTEE: 'An Investigation of the Combustion Method of Sulphur Determination in Ferro-Alloys and Complex Steels.'
Jnl. Iron and Steel Inst., 1954, vol. 177, June, Pt. II, pp. 239–42.

The determination of sulphur in steels may be carried out by direct combustion in oxygen, absorption of the evolved gases in a suitable reagent, and titration of the resulting solution. The main limitation of this procedure is that although the yield of sulphur is constant under given conditions, it is not quantitative. The sulphur content must therefore be calculated with reference to suitable steels, the sulphur contents of which have been established gravimetrically.

Research is in progress with the object of achieving quantitative recovery of sulphur, but the committee which has the investigation in hand considers it advisable, pending further progress, to propose a standardized technique which will make possible closer agreement among laboratories using a combustion procedure. Full details of the recommended method are given, and results of analyses made by it, on a wide range of materials, are quoted to demonstrate its validity. Austenitic nickel-chromium steels and a low-alloy nickel-containing steel, also ferro-alloys of vanadium, tungsten and chromium, are among the materials for which it is suitable. Up to 16 per cent. of molybdenum in steels does not interfere, but the method is not suitable for use on ferro-molybdenum.

Joining of Tubes to Tube Sheets: Procedures Suitable for Various Materials

H. A. HUFF and A. N. KUGLER: 'Welding Tubes to Tube Sheets.' *Mechanical Engineering*, 1954, vol. 76, May, pp. 421–5, 433. (Condensed from *Amer. Soc. Mech. Eng. Paper 53-A-175.*)
Contributed by the Heat-Transfer Division of the American Society of Mechanical Engineers.

This paper makes recommendations on joint design, brazing methods and materials to be used in tube/tube-sheet assemblies. Following general discussion of fundamental requirements common to all such joints, detailed recommendations are made with regard to brazing or braze-welding of the following combinations:—carbon and low-alloy steels, stainless steels, copper alloys, nickel and nickel alloys, aluminium and aluminium alloys, each joined to similar materials; dissimilar-metal combinations (carbon and low-alloy steels to stainless steels, copper and copper alloys, nickel and nickel alloys, or aluminium; stainless steel to copper, nickel and nickel alloys; copper to nickel). It is noted that for three dissimilar-metal combinations, stainless steel to aluminium, copper to aluminium, and nickel to aluminium, it has not yet been found possible to devise methods for welding or brazing.

HEAT- AND CORROSION-RESISTING MATERIALS

Complex Nickel-Chromium-base Alloy for High-Temperature Use

SOC. AUTOMOTIVE ENGINEERS: 'Alloy Sheet, Corrosion- and Heat-Resistant.' A.M.S. Specification 5536, May 1, 1954.
'Alloy, Corrosion- and Heat-Resistant.' A.M.S. Specification 5574, May 1, 1954.

The composition covered by both specifications is as follows:—carbon 0·05–0·15, silicon 1·00 max., manganese 1·00 max., sulphur 0·030 max., phosphorus 0·040 max., chromium 20·50–23·00, cobalt 0·50–2·50, molybdenum 8·00–10·00, tungsten 0·20–1·00, iron 17·00–20·00, per cent., nickel remainder.

5536. The sheet material covered is intended primarily for parts such as welded nozzle diaphragm assemblies, burner-liner parts, tail pipes, exhaust-cone assemblies and other parts requiring oxidation-resistance up to 2200°F. (1205°C.) and relatively high strength above 1500°F. (815°C.).

5574. This specification relates to bars, forgings, and forging stock to be used for production of turbine rotors, shafts, blades, bolts, etc.

Influence of Surface Finish on Fatigue-Resistance at High Temperatures

R. L. FERGUSON: 'A Further Investigation on the Effect of Surface Finish on Fatigue Properties at Elevated Temperatures.' *Nat. Advisory Committee for Aeronautics, Tech. Note 3142*, Mar., 1954; 27 pp.

The investigation reported was made to evaluate the effects of surface roughness on fatigue properties of low-carbon N-155 having a grain size of A.S.T.M. 6 and of S-816 alloy of A.S.T.M. grain size 6–7. (For the compositions of the alloys, see table below.)

Chemical Composition

Alloy	C %	Si %	Mn %	Cr %	Ni %	Co %	Mo %	W %	Nb %	N %	Fe %
N–155	0·13	0·42	1·64	21·22	19·00	19·70	2·90	2·61	0·84	0·13	Bal.
S–816	0·37	0·57	1·31	20·08	19·21	42·79	4·00	4·03	4·30	—	3·31

The tests were made at 80°, 1200°, 1350° and 1500°F. (27°, 648°, 734° and 815°C.), and in addition a study was made of the effect of surface abrasion on the nature, direction, magnitude and depth of residual stresses and of the effect of time and temperature of heating on the relief of these stresses.

The stress-concentration effect of the surface roughnesses investigated was found to lower the fatigue strengths of both N-155 and S-816 as much as 10 per cent. at the temperatures and times considered. This observation was made after the surface compressive stresses induced by roughening, which tend to increase fatigue strength, had been reduced by annealing.

A study of strips roughened by abrasion showed that the abraded surface contains compressive stresses at right angles to the scratches and tensile stresses parallel to the scratches. These residual surface stresses may remain during fatigue cycling at low temperatures and, when of sufficient magnitude, may act to increase fatigue strength appreciably. At elevated temperatures, however, these beneficial stresses were relieved during cyclic stressing and only the detrimental stress-concentration effects produced by abrasion remained. These reduced fatigue strength.

Creep-Rupture Properties of Heat-Resisting Alloy Sheet

A. I. RUSH and J. W. FREEMAN: 'Statistical Evaluation of the Creep-Rupture Properties of Four Heat-Resistant Alloys in Sheet Form.' *Amer. Soc. Testing Materials, Preprint 82*, June 1954; 26 pp.

Among the many new materials which have been developed for use in high-temperature engineering, each type may be expected to have a range in properties which is representative of normal production variations in chemical composition, processing conditions, and heat-treatment. Sound design values therefore require establishment of the limiting variations in properties likely to occur under normal production conditions. The work covered by this paper comprises a statistical evaluation of the ranges in creep-rupture values which may occur in commercially-produced sheet material of the following types:—

Titanium-stabilized 18–8 chromium–nickel steel to A.I.S.I. 321; niobium/tantalum-stabilized 18–8 chromium–nickel steel to A.I.S.I. 347;

N.155 Multimet alloy to S.A.E./A.M.S. 5532 (a complex nickel–chromium–cobalt–base alloy containing tungsten, molybdenum and niobium/tantalum);

Inconel X to S.A.E./A.M.S. 5542 (precipitation-hardening alloy containing, approximately, nickel 73, chromium 14–15, iron 6–7, per cent., with aluminium and titanium).

All four materials are used primarily by the aircraft industry.

Ten sheets of each alloy, from different heats, were used for the tests and, where possible, the material was obtained from several producers. Tests were made at 1200°, 1350° and 1500°F. (648°, 734° and 815°C.), for times up to 80 or 300 hours, depending on the temperature and the material tested. Insofar as the data obtained from the stress-rupture tests permitted, total deformation strengths were determined for elongations of 0·2, 0·5, 1·0 and 2·0, per cent., for time periods of 1, 5, 20, 80 and 300 hours. Duplicate room-temperature tensile tests were also made on material from each of the sheets, in order to establish variations within a given sheet, as well as sheet-to-sheet variations.

The individual values obtained, representative examples of which are reported in the paper, were statistically examined, and as a result average values and standard deviations have been delimited within a closer range than has previously been possible. Further work (on the influence of heat-treatment, cold-work, composition, and other variables) would, however, be necessary to determine fully the causes for some of the scatter of properties found.

Thermal-Stress Fatigue in Austenitic Nickel-Chromium Steels

L. F. COFFIN: 'The Problem of Thermal-Stress Fatigue in Austenitic Steels at Elevated Temperatures.' *Amer. Soc. Testing Materials, Preprint 100a*, June, 1954; 20 pp.

A programme of investigation of the effects of cyclic thermal stress on austenitic steels has been under way for some time at the Knoll Atomic Power Laboratory, Schenectady, N.Y., with a view to obtaining information which can be applied in design and to elucidating the mechanism of thermal fatigue. This paper reports one section of the research, which was planned specifically for the study of some of the mechanisms for localization of fatigue cracks resulting from cyclic thermal conditions in structures. The work was carried out on a Type 347 (niobium-stabilized) austenitic nickel-chromium steel.

The results lead to the conclusion that localization of cyclic strain as a consequence of thermal fluctuations is a principal cause for thermal-stress fatigue failure in structures fabricated from austenitic steel. Inhomogeneities introduced in parts of the material, e.g., by incorrect machining or other form of cold work, are particularly serious in reducing life-to-failure in thermally cycled structures. Relationships between change in plastic strain and cycles to failure are derived from tests made on uniform specimens subjected to both cyclic strain at constant temperature and constrained cyclic thermal strain.

Effect of Alternating Temperature on High-Temperature Strength

J. MILLER: 'Effect of Temperature Cycling on the Rupture Strength of Some High-Temperature Alloys.' *Amer. Soc. Testing Materials, Preprint 100b*, June 1954; 13 pp.

In the investigation reported four alloys (see table on p. 143) were tested under three different types of temperature cycle:—

(1) *Rectangular Temperature Cycle.* A fraction of time under load was spent at a high temperature, the remainder at a lower temperature: the load was removed during heating and cooling. The

Composition and Heat-Treatment of Test Materials

Alloy	C %	Mn %	Cr %	Ni %	Co %	Fe %	Mo %	W %	Ti %	Al %	Other %	Heat-Treatment*
S 816	0·39	1·10	19·92	19·74	42·77	3·39	3·90	4·27	—	—	Nb 3·88	2150°F. (1175°C.) 1 hr., w.q. 1400°F. (760°C.) 12 hr., a.c.
M 252	0·17	1·09	19·13	Bal.	9·77	1·07	10·87	—	2·23	0·47	—	1950°F. (1065°C.) 4 hr., a.c. 1400°F. (760°C.) 15 hr., a.c.
16–25–6	0·086	1·66	15·87	25·50	—	Bal.	6·50	—	—	—	N 0·154	Worked 22% at 1300°F. (705°C.) 1200°F. (540°C.) 8 hr., a.c.
A 286	0·06	1·38	14·71	26·06	—	Bal.	1·22	—	1·92	0·16	V 0·15	1800°F. (980°C.) 1 hr., o.q. 1325°F. (717°C.) 16 hr., a.c.

* w.q., water–quenched. a.c., air–cooled. o.q., oil–quenched.

given cycles were repeated until failure of the specimen occurred.

(2) *Sawtooth Temperature Cycle.* In this series the load was on the specimen continuously and the temperature fluctuated by a given amount above and below the mean temperature.

(3) *Special Temperature Cycle.* This cycle was designed to approximate to the severe temperature changes to which gas-turbine blading may be subjected in service. The specimens were maintained continuously under a stress of 15,000 p.s.i. (7·5 tons per sq. in.) in a furnace controlled at 1500°F. (815°C.). At regular intervals the temperature of the specimen was raised to 1800°F. (980°C.) by passing through it a heavy electrical current. At the end of 60 seconds the current was turned off and the specimen was allowed to cool to the temperature of the furnace.

The experimental data obtained are analyzed by comparing actual rupture lives with values calculated from constant-temperature data according to a method developed by ROBINSON (*Trans. Amer. Soc. Mech. Eng.*, 1952, vol. 74, pp. 777–81). In general, actual and calculated values correlate well, but the observed values tend to be somewhat lower than those calculated. It is considered that, provided a suitable safety factor is applied, such calculations should be of practical value in design. It is, however, emphasized that where conditions are such that thermal gradients are large enough to produce significant thermal stresses failure could occur much sooner than might be expected on the basis of calculations which neglect such effects.

Elevated-Temperature Short- and Long-Time Tests on Low-Nickel Alloy Steels

See abstract on p. 138.

Influence of Load-Cycling on Behaviour of Materials at Elevated Temperatures

W. F. SIMMONS and H. C. CROSS: 'Constant and Cyclic-Load Creep Tests of Several Materials.'
Amer. Soc. Testing Materials, Preprint 100d, June 1954; 13 pp.

The paper reports results of a limited series of tests made at the request of a group of U.S. aircraft companies, with the primary purpose of determining whether alternating periods of load and rest would have the same effect as continuous loading, on deformation characteristics at elevated temperatures.

Three materials were selected for test, representative of different types used in the aeronautical industry, in different temperature ranges. Alclad aluminium alloy was tested at 300°F. (150°C.); chromium-molybdenum steel, to S.A.E. 4130, at 800°F. (425°C.); austenitic chromium-nickel steel to A.I.S.I. 310 (chromium 24–26, nickel 19–22 per cent.) at 1500°F. (815°C.). All the materials were stressed at approximately 75 per cent. of their short-time yield strength at the test temperature, for ten to twenty one-hour periods, with one-hour rest periods between loadings. The results of these tests were compared with those of constant-load tests made under similar conditions of load and temperature.

With the possible exception of the aluminium alloy, none of the materials showed any evidence that cycling of the load (in the conditions used) increased the rate of creep, and, since none of the cyclic-load tests showed creep rates less than one half of the rate found in the constant-load test, there was no evidence of any recovery during the low-load part of the cycle. The data obtained, although incomplete, are considered to indicate that it is probably safe to design for cyclic-load conditions on the basis of values given by constant-load tests.

Thermal-Shock Tests on Austenitic Nickel-Chromium Steels

R. A. TIDBALL and M. M. SHRUT: 'Thermal-Shocking Austenitic Stainless Steels with Molten Metals.' *Trans. Amer. Soc. Mechanical Engineers*, 1954, vol. 76, May, pp. 639–43.

Thermal shock, and fatigue resulting from thermal cycling, are factors requiring consideration in the design of high-temperature heat-transfer systems in which molten metals are employed as heat-transfer fluids.

This paper covers a section of the work done on this subject under a project arranged between the Knoll Atomic Power Laboratory of the General Electric Company and the Mines Safety Appliances Company, Callery, Pa., at the request of the Nuclear Power Division of the U.S. Bureau of Ships, Navy Department. Under this programme, a series of austenitic stainless-steel pipe and pipe-weld specimens of large size is being subjected to tests to determine the effects of thermal shock on welds and to ascertain modifications required in welding technique. Each specimen is to be shocked 2,500 times by quenching heated sections from 850°F. (455°C.) with cool sodium-potassium alloy. The minimum rate of temperature change is specified as 100°F. (55°C.) per second on the inner fibre of the wall. The upper temperature limit and the rate of cooling were chosen as being the first representative conditions by which satisfactory shocking conditions could be easily produced and which would give results typical of service performance.

The equipment used in the tests is described and illustrated, also the methods used in measuring the temperatures of the transient fluid and the pipe wall.

The data obtained indicate that, while much further work, on other alloys, forms, and temperature cycles, is needed fully to evaluate the problems involved in thermal shocking in liquid-metal systems, it appears safe to use current methods of design in cases in which stresses caused by thermal shock are not in excess of those described in the report. The most serious problem is considered to be elimination of microfissures in the root pass of the welds, which must be secured by means of improved welding techniques.

Creep Properties of Copper-Nickel Alloys

J. H. PORT and A. I. BLANK: 'The Creep Characteristics of Copper-Nickel Alloys at 300°, 400° and 500°F.' *Amer. Soc. Testing Materials, Preprint 106b*, June, 1954; 12 pp.

Although copper-nickel alloys have been in regular use for many years in applications involving stress at elevated temperatures, e.g., in heat exchangers and unfired pressure vessels, relatively little information on the creep properties of such alloys has previously been published. The principal paper on this subject was that by BURGHOFF *et al.* (*Proc. Amer. Soc. Testing Materials*, 1942, vol. 15, No. 8–9, p. 130). That paper dealt with a low-iron 70–30 copper-nickel alloy and, for comparison, the data from it are embodied in the present report, which covers tests on 90–10 copper-nickel alloys containing (*a*) 0·68 per cent. of iron, and (*b*) 1·08 per cent. of iron, and 80–20 copper-nickel containing 0·19 per cent. of iron. The creep tests were made on $\frac{1}{8}$-in. diameter rod drawn to size, mechanically straightened, and cut to length. The 90–10 alloy containing 1·08 per cent. of iron was tested as drawn to 21 per cent. reduction in area and as annealed to 0·025-mm. grain size: the other materials were all annealed after straightening. The tests were run at constant load, in most cases for 6,000 hours, at 300°, 400° and 500°F. (150°, 205° and 260°C.).

The results are recorded in detail, and an account is given of microscopical examination of the specimens before and after testing.

At the three test temperatures the creep strength of the annealed 90–10 alloy containing 1·08 per cent. of iron was two or more times that of the same type of alloy containing only 0·68 per cent. of iron. In the higher-iron alloy the presence of free iron was observed (using the technique described by PALMER and WILSON; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, 1952, vol. 194, p. 55), but in the lower-iron type no free iron was detected. In the annealed condition there was no significant difference between the creep strengths, at 300°F. (150°C.) of 90–10 copper-nickel containing 1·08 per cent. of iron, 80–20 copper-nickel containing 0·19 per cent. of iron, and the 70–30 copper-nickel containing 0·03 per cent. of iron tested by BURGHOFF. At 500°F. (260°C.) the creep strengths of the iron-containing 80–20 and 70–30 alloys were closely similar, both being considerably higher than that of the annealed 90–10 copper-nickel containing 1·08 per cent. of iron.

The creep strength of this latter alloy was much improved by cold-drawing to 21 per cent. reduction in area: at 300°F. (150°C.) it was superior, in the cold-worked condition, to all the annealed materials, and at 500°F. (260°C.) its creep strength was approximately equal to that of the annealed 70–30 and 80–20 alloys. For creep rates produced by stresses above the proportional limits of these materials the total extension of the hard-drawn 90–10 copper-nickel is very much less than that of the annealed materials, due to the fact that the initial extension is significantly less for the drawn material.

Heat-Capacity of High-Nickel Alloys

T. B. DOUGLAS and J. L. DEVER: 'Heat Capacity of Four Alloys: Nichrome V and Stainless Steels Types 347 and 466, 0°–900°C.; Monel 0°–300°C. *U.S. Atomic Energy Commission Publn.* 1953; *Nat. Bur. Standards 2302*; 23 pp.

The apparatus used in the experiments, and the method of determination, were described in earlier papers from the Bureau of Standards laboratory (*Jnl. Research, Nat. Bur. Standards*, 1947, vol. 38, pp. 583, 593; 1950, vol. 45, p. 23). The results of the measurements made on the four alloys mentioned above are summarized in *Metallurgical Abstracts*, 1954, vol. 21, June, p. 865.

Influence of Selective Oxidation on Surface Structure of Nickel-Chromium Alloy

J. BENARD and J. MOREAU: 'The Appearance of an Unusual Type of Microstructure at the Surface of a Nickel-Chromium Alloy Resulting from Selective Oxidation.' *Comptes Rendus*, 1954, vol. 238, Apr. 21, pp. 1659–61.

The authors describe observations made on a nickel-chromium alloy (4·6 per cent. chromium) exposed, at 1200°C., first to a mixture of hydrogen and water vapour, and subsequently, at the same temperature, in very pure hydrogen or argon.

The structure developed at the surface by the oxidizing treatment (a lined 'relief type' formation showing parallel lines of oxide of varying thickness) is illustrated in the original. It is attributed by the authors to chromium depletion of the metallic surface due to selective oxidation. Treatment in hydrogen (which reduces the oxide), or in argon (which causes it to coalesce) causes disappearance of the 'relief' structure. The mechanism of the effects is discussed in relation to observations which have been made by other investigators on copper and on silver.

Sigma Phase: Formation, Control, Identification

R. K. POOLE: 'Sigma: an Unwanted Constituent in Stainless Weld Metal.' *Metal Progress*, 1954, vol. 65, June, pp. 108–12.

The author reviews his subject in three sections:—

(1) *Formation of Sigma.* Sigma phase forms by either of two mechanisms: (*a*) in weld deposits containing some ferrite sigma appears in the ferrite areas in the weld metal; *or* (*b*) it may be formed directly or indirectly from austenite, occurring principally at the grain boundaries. Both types of transformation are illustrated by photomicrographs, and the influence of time and temperature of heating, on susceptibility of duplex and fully austenitic steels to formation of sigma, is demonstrated by curves relating to typical weld metals. The embrittling effect of sigma phase in ferrite-containing steels is discussed in relation to a steel containing chromium 17, nickel 12, molybdenum 2·5, per cent., and brief reference is made to the very sparse information which is at present available on the loss of ductility resulting from sigma in fully austenitic weld metal.

(2) *Control of Sigma.* The deleterious effects of sigma phase in partially ferritic weld metal may be counteracted in two ways:—(*a*) by balancing of the austenite-forming and the ferrite-forming elements in the composition of the electrode core wire, or by adjusting the nature of the coating *or* (*b*) by heat-treatment of the two-phase weld metal at 1920°F. (1045°C.), i.e., a temperature above that at which sigma is formed, with subsequent water quenching. The beneficial influence of such thermal treatment is believed to be due to solution of some of the pre-existing ferrite into the austenite, and to the agglomeration or spheroidization of the remaining ferrite. Sigma later formed from ferrite in steel after such treatment is in a discontinuous pattern and has less effect on the properties of the steel than the sigma formed in steels which have not been so treated. The author considers that the only well established method for controlling sigma in fully austenitic weld metal is periodic high-temperature treatment, which, however, is not always practicable. It is pointed out that while elevated-temperature impact tests indicate that the presence of sigma phase does not embrittle susceptible alloys so seriously at service temperatures as at room temperature, it is nevertheless imperative that embrittlement at room temperature be prevented, in view of stresses which inevitably arise from cooling and heating during shut-downs and from any other form of thermal cycling.

(3) *Identification of Sigma.* Identification of sigma when occurring in very small particles is complicated by its similarity to finely divided carbides. For its identification in particles sufficiently large to appear as circles or islands at 1000 magnification, the author recommends etching techniques described by EMMANUEL in *Metal Progress*, 1947, vol. 52, p. 78, and by GILMAN in *Transactions of the American Society for Metals*, 1954, vol. 44, p. 566.

Sigma can be positively identified by X-ray diffraction, but it must first be isolated or selectively concentrated. Some interference from tetragonal chromium carbide (Cr_7C_3) and from niobium has been reported, and X-ray methods suffer from the fact that the particle size and distribution in the original matrix cannot be determined. The latter factors are of considerable importance, since large particles of sigma segregated at grain boundaries have a more harmful effect in lowering mechanical properties than an equal amount of sigma evenly distributed in fine particles.

Etching Technique for Identification of Sigma Phase in Austenitic Steels

'Experiments on Etching Procedures for the Identification of the Sigma Phase in Austenitic Chromium-Nickel Stainless Steels.'
Contained in Report of A.S.T.M. Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys.
Proc. Amer. Soc. Testing Materials, 1953, vol. 53, pp. 143–68; disc., pp. 177–80.

In response to requests from industrial users of stainless steels, A.S.T.M. Committee A-10 has been, since 1947, engaged in a study of various etching techniques, with a view to developing a simple procedure for identification of sigma phase in high-alloy chromium-nickel steels. Specimens of three steels (selected to provide the desired variations in sigma content) were appropriately heat-treated, and have been examined by ten co-operating laboratories in the U.S.A. and Canada. The steels used were of the compositions given in the Table on p. 146.

Methods of test included an exhaustive investigation of the ability of various types of etchant to reveal the presence of sigma, supplemented by determination of impact properties in various conditions, X-ray diffraction studies, measurements of magnetic permeability, hardness tests, and exposure to the standard A.S.T.M.

Chemical Compositions of Steels Examined

Laboratory	Steel No. 1			Steel No. 2			Steel No. 3		
	A %	B %	C %	A %	B %	C %	A %	B %	C %
Carbon	0·059	0·065	0·057	0·085	0·079	0·081	0·071	0·070	0·067
Silicon	0·35	0·34	0·34	0·48	0·49	0·48	0·67	0·72	0·69
Manganese	0·45	0·46	0·46	1·67	1·66	1·66	1·60	1·57	1·60
Chromium	18·18	18·22	18·19	17·71	17·86	17·73	18·39	18·34	18·30
Nickel	9·27	9·33	9·33	9·35	9·45	9·45	13·49	13·57	13·48
Molybdenum	0·03	0·04	0·06	3·51	3·75	3·44	3·51	3·70	3·48
Nitrogen	—	0·034	—	—	0·054	—	—	0·060	—

boiling nitric-acid corrosion test. The behaviour of the steels under attack by the individual etching solutions, and the nature of the structures revealed, are described in detail and are illustrated in an extensive series of photomicrographs. The results of the metallographic examinations made, together with the data obtained from the other forms of test employed, are summarized as under:—

'The sigma phase which develops in the austenitic stainless steels cannot be identified with certainty by the use of an etching reagent alone. The sigma phase can be identified metallographically on properly etched samples provided the particles are large enough, and the composition and thermal heat-treatment of the austenitic chromium-nickel stainless steel are known. In other words, this work has shown that once the presence of the sigma phase has been established through X-ray diffraction technique in austenitic chromium-nickel stainless steels of certain compositions and certain thermal treatments it can be detected by etching with the proper reagents.

'The etching reagents that will outline the sigma phase are aqua regia in glycerine, Vilella's reagent, and Marble's reagent. Murakami's solution and the electrolytic 10 per cent. sodium-cyanide reagent will tint the phase. The etchants that dissolve the phase are hot modified Murakami's solution, 2 and 10 per cent. chromic acid, ammonium persulphate, perchloric acid, and the electrolytic 5 per cent. nital solution.

'The procedure that can be used for identifying the sigma phase under known conditions of composition and thermal treatment of austenitic stainless steels is to use aqua regia in glycerine, Vilella's, or Marble's reagent followed by Murakami's reagent either as such or modified, electrolytic 10 per cent. sodium cyanide, 2 and 10 per cent. chromic acid, ammonium persulphate, perchloric acid, or the electrolytic 5 per cent. nital etch.

'Other facts that appear to be established under the conditions of these tests are as follows:—

'1. The sigma phase does not develop in the low-carbon 18–8 steel under the conditions of thermal treatment studied. Sigma phase does develop in the molybdenum - bearing austenitic chromium - nickel steels after heat-treatment involving temperatures of 1350° and 1500°F. (735° and 815°C.).

'2. Development of sigma phase in the molybdenum-bearing austenitic chromium-nickel stainless steels brings about a marked decrease in the toughness of the steels. The toughness of the 18–8 steel was also decreased somewhat by holding at temperatures of 1200°, 1350° and 1500°F. (650°, 735° and 815°C.), but this slight drop in toughness may be accounted for by the presence of precipitated carbides.

'3. The most sensitive indication of the presence of sigma was the loss of toughness in the Charpy impact test.

'4. The absence of sigma in X-ray diffraction patterns obtained by methods used in this investigation or in structures developed by the wide variety of etching reagents used appears to be no sure indication that this phase is not present.

'5. The presence of sigma phase brings about an increase in hardness in the segregated bands of transformed alpha phase.

'6. The sigma phase identified in the molybdenum-bearing stainless steels is non-magnetic in character.

'7. A new phase designated as chi was detected by X-ray, along with the sigma phase, in the molybdenum-bearing stainless steels. This new phase was not found to exist in the austenitic chromium-nickel steel containing no molybdenum.'

In connexion with this research, additional tests were made in one of the co-operating laboratories, to determine whether any relationship exists between the path of the corrosive attack and the location of metallographically identified sigma or chi particles. The conclusion drawn from examination of the nature of the attack on the three steels is that 'there is strong evidence that the relatively high rates of nitric-acid attack on samples of steels 2 and 3 which had been re-heated at 1500°F. (815°C.) are not due to solution of sigma or chi particles, nor to accelerated attack upon the matrix immediately surrounding these particles. It is not considered possible to decide whether the overall chromium depletion of the matrix material, due to formation of sigma or chi phase, is a factor in such deterioration.

Metallographic Identification of Sigma Phase

F. J. AYMA: 'Metallographic Identification of Sigma Phase in a Ferritic Chromium Steel and in Austenitic Chromium-Nickel Steels.' *Rev. de Ciencia Applicada*, 1954, vol. 8, Jan.-Feb. and Mar.-Apr., pp. 18-34, 112-31.

The occurrence of sigma phase and means for its identification were studied in a ferritic 14 per cent. chromium steel and in austenitic chromium-nickel steels of the 18-8 and 25-20 types. The paper is profusely illustrated by photomicrographs. Metallographic examination was supplemented by determinations of changes in hardness and loss of ductility associated with formation of sigma.

Tests on Superheater Materials in Experimental Installation

B. RONAY and W. E. CLAUTICE: 'Evaluation of Superheater Materials for High-Temperature Steam.' *Welding Jnl.*, 1954, vol. 33, Apr., Suppl., pp. 199S-205S.

In connexion with the development of improved materials for superheaters, the American Society of Mechanical Engineers' Research Committee on High-Temperature Steam Generation is sponsoring tests, at the U.S. Naval Engineering Experiment Station, in which selected materials are being subjected to conditions designed to determine their behaviour in contact with superheated steam at various temperatures. This report describes plans for tests which will be designed to evaluate: (1) the nature, thickness, permanence, and thermal conductivity of oxide films formed on steam-swept surfaces; (2) the metallurgical stability of the various metallic materials over long periods of time; and (3) the effects of repetitive thermal shock. The plan of the steam-exposure experimental unit is described and illustrated, and conditions of exposure are detailed. The materials to be tested include various types of low-alloy chromium-molybdenum steel, six types of austenitic nickel-chromium steel, Armco 17-14 chromium-nickel-iron alloy containing additions of copper and molybdenum, Timken 16-25-6 chromium-nickel-molybdenum steel, Inconel (nickel 78, chromium 14, iron 6, per cent.), Incoloy (nickel 35, chromium 20, per cent., balance iron) and a low-alloy molybdenum-vanadium steel.

Nickel-containing Materials in Experimental Superheater

F. EBERLE, F. G. ELY and J. A. DILLON: 'Experimental Superheater for Steam at 2000 p.s.i. and 1250°F. Progress Report after 12,000 Hours of Operation.' *Trans. Amer. Soc. Mechanical Engineers*, 1954, vol. 75, May, pp. 665-75; disc., pp. 675-7.

The generation and use of steam at higher pressures and temperatures offers a direct and important means of improving power-plant efficiency, but current practice is limited by materials available for construction of the high-temperature sections of superheaters and turbines, and advances can be made only as new alloys are developed which, while having mechanical stability and resistance to corrosion at higher temperatures, will be capable of commercial fabrication at reasonable cost.

Certain new materials which had been developed during the war showed properties promising the possibility of extending steam temperatures beyond the 1050°F. (565°C.) limit then prevailing, and, in order to supplement laboratory data on these alloys, a test superheater embodying such alloys was constructed and installed in an operating boiler in the Twin Branch plant of The Babcock and Wilcox Company. The experimental element, which was started up in March 1950, functions as a small superheater, exposed to hot gases from pulverized-coal firing, and receiving steam at 2,000 p.s.i. and 1000°F. (540°C.), which, by actual heat transfer, is increased to 1250°F. (675°C.) at the outlet of the test element. An account of experience during the first two years of its running was presented in 1952 (*ibid.*, vol. 74, pp. 803-12). The present report covers the succeeding two years, and includes preliminary information provided by metallurgical examination of a number of specimens removed from the element after approximately 7,000 hours of operation.

The materials embodied in the superheater, in positions which are indicated in the paper, include 18-8 chromium-nickel steels of straight, niobium-stabilized, titanium-stabilized, molybdenum-containing and molybdenum+niobium-containing types, 16-25-6 chromium-nickel-molybdenum steel, an experimental 15-15 chromium-nickel-iron alloy, and an Armco alloy containing chromium 17, nickel 14, per cent., with additions of copper and molybdenum.

The authors report in considerable detail on the behaviour of the respective materials, from the point of view of resistance to corrosion, stability of mechanical and physical properties, etc., as evaluated by various tests. The general conclusion drawn is that 'examination of tube sections removed after 6,950 hours of operation has shown that no serious impairment of essential properties has occurred in any one of the seven alloys employed. Among the weld metals 18-12-Mo and 17-14-Cu-Mo have suffered considerable impact embrittlement. However, there is reason to believe that an improved 18-12-Mo electrode can be developed which will deposit weld metal free of tendency to dangerous embrittlement. An improved 17-14-Cu-Mo electrode is already commercially available. In view of the satisfactory behaviour of the tubing materials, it may not be unrealistic to envisage the commercial use of superheaters operating with steam above 1200°F. (650°C.) in the not-too-distant future.'

Corrosion of Metallic Materials by the Products of Combustion of Gaseous Fuels

H. A. PRAY, R. S. PEOPLES and E. WHITE: 'The Corrosion of Metals and Materials by the Products of Combustion of Gaseous Fuels.' *Amer. Gas Assocn., Rept. 4 to Committee on Domestic Gas Research Project D.G.R.-4-CH*, June, 1953; 27 pp.

The objective of this project has been to determine and study the various factors influencing the

corrosion behaviour of metals and other materials in the presence of the combustion products of fuel gases (both sulphur-bearing and sulphur-free), under laboratory conditions simulating actual operation.

This report summarizes the work done to date, which has been covered by three previous reports and the present paper:—

I. Survey of the Literature on Corrosion by Flue Gases.

II. Corrosion of Mild Steel by the Products of Combustion of Gaseous Fuels.

III. Behaviour of Various Materials Used or Proposed for Gas Appliances.

The tests covered by Report III led to the following conclusions (considering only corrosion behaviour under all the test conditions used, and neglecting such factors as cost, fabrication, and mechanical properties):—

'The stainless steels were, by far, the most resistant of the materials studied. Aluminium alloys, Alclad, aluminized steel, and aluminium-coated hot-sprayed steel also showed excellent behaviour and closely followed the stainless steels.

'While not showing the high degree of resistance of the above materials, the low-alloy steels, copper, and alloy cast irons were considerably more resistant than carbon steel and unalloyed cast irons.'

In the experimental work first published in the present report (No. IV) the behaviour of carbon steel, aluminized steel, 18–8 and 18–8–Nb chromium-nickel steels, and two types of straight-chromium steel was investigated under continuous heating at 875°, 1000°, 1100°, 1200° and 1400°F. (468°, 538°, 593°, 648° and 760°C.).

Continuous-heating tests, in flue products from 1000-B.t.u. fuel, sulphur-free or containing 25·0 grains of sulphur, indicated that all the materials showed good resistance to oxidation under the test conditions at 875°F. (468°C.), although the carbon steel was not so resistant as the other materials. Aluminized steel showed excellent resistance up to 1200°F. (648°C.). The rates of attack on the stainless steels increased slightly when the temperature was raised to 1400°F. (760°C.), but even at that temperature the rates were low. Under the conditions of continuous heating used (dry, with no condensation or re-evaporation), the presence of sulphur has apparently no great effect on the corrosion behaviour of any of the materials studied.

The effect of welding operations was determined on the carbon steel, the aluminized steel and the two types of nickel-chromium stainless steel: in no case was there evidence that the welding operation had any detrimental effect on corrosion-resistance, within the exposure conditions studied.

Further tests, on carbon steel and aluminized steel only, at 80°–400°F. (26·8–204°C.) indicated that if the sulphur content of fuel gas does not exceed approximately 0·4 grain per 100 cu. ft. of 1000 B.t.u. fuel gas no serious corrosion problem will arise: increase to 1 grain per cu. ft. causes sharp rise in corrosion of carbon steel, though not of aluminized steel. This series included cyclic tests within the temperature range mentioned. Cyclic tests above the dew point (400°–800°F.; 204°–426°C.) resulted in the same rates of corrosion as were caused by continuous heating at 600°F. (315°C.) or under cyclic operation below the dew point. Applied stress was found to exert no appreciable effect on the corrosion behaviour of the carbon steel, either in the presence or absence of sulphur in the flue products.

The possible influence of precipitated carbides in sensitized nickel-chromium steel was studied on the unstabilized 18–8 steel. The specimens were exposed to cyclic test conditions (80°–400°F.: 26·8°–204°C.) in the presence of sulphur-bearing flue products. On the basis of average rates of penetration, little difference was observed between those which had been sensitized and those which had been quench-annealed, but the maximum penetration rates for the sensitized specimens were considerably greater than for the quench-annealed samples, indicating that for optimum corrosion-resistance in the type of conditions studied 18–8 steel of the unstabilized type should be in the quench-annealed condition.

Brightray 'C' Resistance Wire and Tape

HENRY WIGGIN AND CO., LTD.: 'A New Type of Brightray 'C' Resistance Wire and Tape for Heating Elements.' *Publn. 765*, 1954; 4 pp.

This publication announces the development of an improved grade of the 80–20 nickel-chromium resistance alloy known as Brightray 'C': it is claimed to give substantially longer life under conditions of intermittent heating. The new material has a slightly higher specific electrical resistance than the alloy which it replaces: in the oxidized annealed condition the value is 115 microhms/sq. cm./cm. at 20°C. Its specific gravity is 8·34, i.e., rather lower than that of the former Brightray 'C'.

Nickel-containing Alloys for Pressing of Beryllium Powder

N. P. PINTO: 'The Warm Pressing of Beryllium Powder.' *Jnl. of Metals*, 1954, vol. 6, May, Pt. II, *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 629–33.

The paper reports development of a method for compacting of beryllium powder below the recrystallization temperature: compacts made under optimum conditions show strength and hardness higher than cold-worked beryllium. Although most of the data relate to compacting *in vacuo*, the evidence obtained in these tests indicates that warm pressing may be adapted to commercial production of beryllium parts.

In describing the methods and equipment used, the author notes that a complex nickel-containing high-temperature alloy*, cast and heat-treated, was found to be a very satisfactory die material: such dies could be used for more than 50 runs, at temperatures up to 750°C., without observable wear or distortion. Other high-temperature alloys are under test. The availability of these heat-resisting materials considerably

* Nickel 30, cobalt 21, chromium 20, iron 18, tantalum 2·2, molybdenum 3·1, tungsten 2·2, manganese 1·5, silicon 1·0 carbon 1·0, per cent.

extends the temperature range in which hot pressing may be performed, and appreciably improves the prospects of commercial development of hot-pressing methods.

Ceramic Materials for Use at High Temperatures: Review

A. PECHMAN: 'Ceramics for High-Temperature Applications. A Survey of Materials used as Coatings for, or in Combination with, Metals.' *Aircraft Engineering*. 1954, vol. 26, May, pp. 157–60.

This well-documented review summarizes the present stage of development, in sections covering, respectively, the following aspects of the subject:—the nature of ceramics, the main types of oxide refractories (alumina, magnesia, zirconia, beryllia, thoria); ceramic coatings (composition, uses, service experience in the aeronautical field, and potential developments in this and other applications); ceramic-metallic materials (production methods, composition, uses).

Resistance of Iron-Nickel-Chromium Alloys to Salt-Bath Corrosion

J. H. JACKSON and M. H. LACHANCE: 'Resistance of Cast Fe–Ni–Cr Alloys to Corrosion in Molten Neutral Heat-Treating Salts.' *Trans. Amer. Soc. Metals*, 1954, vol. 46, pp. 157–83.

The paper comprises an amplified report on the research of which some results were published in *Alloy Casting Bulletin*, 1952, No. 16, pp. 1–5, 7–10; see abstract in *Nickel Bulletin*, 1953, vol. 26, No. 1, pp. 21–2.

Behaviour of Nickel in Contact with Molten Sodium Hydroxide

D. R. MOSHER and R. A. LAD: 'Kinetic Study of Mass Transfer by Sodium Hydroxide in Nickel under Free-Convection Conditions.' *Nat. Advisory Committee for Aeronautics, Research Memorandum E53K24*, Mar. 10, 1954; 14 pp.

There is general interest in molten sodium hydroxide as a high-temperature heat-transfer medium but to date no container material has been found in which corrosion and mass transfer do not occur. This paper reports a study on the behaviour of 'L' nickel, a low-carbon grade in which corrosion by molten sodium hydroxide is limited to almost uniform removal of metal in the high-temperature region (without intergranular penetration) and the formation of a crystalline nickel deposit in the cooler regions. Static capsules, each containing a weighed disc specimen and a weighed quantity of sodium hydroxide, were subjected to tests to determine the effect of temperature level, temperature gradient and duration of test, as influencing corrosion and mass transfer by molten sodium hydroxide under free-convection conditions. A base temperature range from 1000° to 1600°F. (538° to 871°C.) was studied. Rate of mass transfer was found to be strongly dependent on both temperature level and gradient. For test durations up to 200 hours the rate showed little tendency to decrease, although the concentration of nickel in the melt approached a limiting value after 100 hours.

Resistance of Metals and Alloys to Molten Lithium

W. D. WILKINSON and F. L. YAGGEE: 'Attack on Metals by Lithium.' *U.S. Atomic Energy Commission, Publn. ANL-4990*, 1950; 36 pp.

The attack of lithium, at 300° and 600°C., on the following materials, was studied:—nickel, iron, thorium, beryllium, Monel, Inconel, carbon steel, austenitic nickel-chromium and nickel-chromium-molybdenum steels, straight-chromium corrosion-resisting steels, and aluminium bronze. The conditions of exposure, and the results obtained, are summarized in *Metallurgical Abstracts*, 1954, vol. 21, p. 702. Low-carbon iron and steels, including the austenitic nickel-chromium-molybdenum type, and beryllium showed the best resistance to attack at 600°C., followed closely by thorium and low-carbon high-chromium steels. Aluminium bronze and Monel were attacked, even at the lower temperature (300°C.): nickel, Inconel, 18–8 chromium-nickel steel, and high-carbon chromium steels showed an intermediate degree of resistance.

Nickel-Chromium-Boron Alloy Facing for Wear- and Corrosion-Resistance

L. V. LA ROU: 'Sprayed-on, Fusion-bonded Coatings Increase Life of Pump Parts.' *Oil and Gas Jnl.*, 1954, vol. 52, Mar. 29, pp. 118, 120–1.

Much increased life and improved surface is obtained, in oil-producing and -refining equipment, by facing with Colmonoy, a nickel-chromium-boron alloy, applied in thicknesses ranging from 0·030 to 0·060 in. After preparation of the surface of the pump or other part, by machining and grit blasting, the work is rotated in a lathe while the alloy powder coating is applied by spraying with a pistol unit, after which the coated part is again rotated while an oxyacetylene torch is applied to the surface, to produce a fusion-bonded, non-porous, welded overlay. The final step is finish-grinding to required dimensions. The treated surface has a Rockwell C hardness of 56–61, and is characterized by high resistance to abrasion, corrosion, and galling. It also shows good resistance to impact and maintains a high degree of hardness at red heat. The nickel-chromium-boron alloy, which melts at 1900°F. (1036°C.), can be bonded without difficulty to steels, stainless steels, some cast irons, and some copper alloys.

Typical applications of the process, and the satisfactory results obtained by it, are illustrated in this article by photographs of Spraywelded parts used in the oil industry, of which the following details are given:—

(1) A plunger which had given 22 months' service in salt water, outlasting, by about eight times, an uncoated plunger in similar service, and obviating daily maintenance of gland packing; (2) a petrol pump plunger which had likewise given eight times the length of service of an uncoated specimen; (3) a coated

pump plunger after a year of service in handling dilute hydrofluoric acid, showing an increased life of six times in comparison with an uncoated part.

See also—

S. M. HOLGATE: 'Spraywelding. A Modern Hard-Facing Technique.' *Electroplating*, 1954, vol. 7, June, pp. 239–42, 245.

This paper also describes in some detail the equipment and methods used in Spraywelding with Colmonoy alloys. The microstructure of cross-sections of the deposits, before and after fusing-on to the basis material, is illustrated. The compositions of the three grades of Colmonoy alloy used for hard-surfacing are shown in the table below:—

	Ni %	Cr %	B %	Fe %	Si+C %
Colmonoy 6 ..	65-75	13-20	2·75-4·75	Bal.	10 max.
Colmonoy 5 ..	71-81	10-17	2-4	Bal.	9 max.
Colmonoy 4 ..	75-85	8-14	2-3	Bal.	8 max.

A critical discussion of the scope of application of Colmonoy hard-surfacing concludes with a list of some of the uses for which such treatment has proved advantageous:—pump rods and sleeves, neck rings, plungers and shafts, exhaust valves and valve spindles, plug gauges, lathe centre tips, sprocket shafts, rollers and other miscellaneous shafts, sleeves, etc.

Austenitic Steel Piping for High-Temperature Service: A.S.T.M. Specification

AMER. SOC. TESTING MATERIALS, COMMITTEE A-1 ON STEEL: 'Proposed Tentative Specifications for Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service.'

Contained in *A.S.T.M. Preprint 1*, June, 1954, pp. 25–34.

Four grades of steel are covered, see Table below.

Tensile, bend, flattening and hydrostatic tests are specified, and requirements for surface finish are included. In connexion with pipe required for special purposes, provision is made for additional inspection, e.g., by etching tests, provision of photomicrographs, and ultrasonic testing.

Precipitation-Hardenable Corrosion- and Heat-Resisting Steels: S.A.E./A.M.S. Specifications

The following are among specifications recently issued by the Society of Automotive Engineers, in their Aeronautical Materials series.

'Steel Sheet and Strip, Corrosion-Resistant; Precipitation-Hardening, 200,000 p.s.i. (min.).' A.M.S. 5529

'Steel Tubing, Welded, Corrosion-Resistant, Precipitation Hardening.' A.M.S. 5568

'Steel (Bars, Forgings and Forging Stock) Corrosion-Resistant, Precipitation-Hardening.' A.M.S. 5644

In all three cases the composition specified is:—carbon 0·09 max., manganese 1·00 max., silicon 1·00 max., phosphorus 0·040 max., sulphur 0·030 max., chromium 16·00–18·00, nickel 6·50–7·75, aluminium 0·75–1·50, per cent. All are dated May 1, 1954.

Modern Stainless Steels: Compositions and Properties

R. H. ABORN: 'Modern Stainless Steels.'

Metal Progress, 1954, vol. 65, June, pp. 115–25.

A review of the development of the stainless steels; the composition and structural characteristics of the main classes of stainless steels and alloys; the chemical properties of the respective grades and their ability to resist various types of corrosive attack; oxidation- and scaling-resistance; mechanical properties. Later sections of the review deal with factors involved in selection of stainless steels for individual applications (e.g., in the automotive, aircraft, architectural, food-handling and chemical-engineering industries), and with some types which have recently been developed, among which mention is made of precipitation-hardening varieties and of chromium-nickel-manganese compositions.

Chemical Requirements

Identification Symbol	C %	Si %	Mn %	S %	P %	Ni %	Cr %	Mo %	Ti %	Nb %
TP 304: Cr-Ni ..	0·08 max.	0·75 max.	2·00 max.	0·030 max.	0·030 max.	8·0-11·0	18·0-20·0	—	—	—
TP 321: Cr-Ni-Ti	0·08 max.	0·75 max.	2·00 max.	0·030 max.	0·030 max.	9·0-13·0	17·0-20·0	—	(a)	—
TP 347: Cr-Ni-Nb	0·08 max.	0·75 max.	2·00 max.	0·030 max.	0·030 max.	9·0-13·0	17·0-20·0	—	—	(b)
TP 316: Cr-Ni-Mo	0·08 max.	0·75 max.	2·00 max.	0·030 max.	0·030 max.	11·0-14·0	16·0-18·0	2·0-3·0	—	—

(a) The titanium content shall be not less than five times the carbon content and not more than 0·60 per cent.
(b) The niobium content shall be not less than ten times the carbon content and not more than 1·00 per cent.

Extra-Low-Carbon Austenitic Steels

R. E. PARET: 'Low-Carbon Stainless Resists Intergranular Corrosion.' *Iron Age*, 1954, vol. 173, May 6, pp. 132–4.

The author urges the advantages of extra-low-carbon stainless nickel-chromium steels for service involving exposure in the sensitizing range. Table I, below, is used to demonstrate the well-defined improvement in resistance to intergranular corrosion which occurs when the carbon content is lowered to about 0·03 per cent. (All specimens were heated for 10 minutes at 1075°F. (580°C.), re-heated to 650°F. (345°C.), and air-cooled.)

Mechanical properties typical of extra-low-carbon nickel-chromium steels are shown in Table II.

Table

Group I Cr 17·83–18·61% Ni 9·92– 9·97%		Group II Cr 18·22–18·57% Ni 10·31–10·95%	
C %	Corrosion Rate in./mth. in boiling 65% HNO_3	C %	Corrosion Rate in./mth. in boiling 65% HNO_3
0·018	0·00066	0·024	0·00080
0·022	0·00081	0·026	0·00087
0·025	0·00075	0·027	0·00073
0·027	0·00105	0·032	0·00171
0·042	0·00620	0·049	0·00550
0·045	0·00520	0·050	0·00780

Standard Methods for Analysis of Iron and Steel

See abstract on p. 140.

Determination of Sulphur in Steels by the Combustion Method

See abstract on p. 141.

Oxalic-Acid Etch Test for Stainless Steels

J. D. ROACH and H. H. HOLLENBECK: 'Electrolytic Etch Cuts Corrosion Test Time.' *Iron Age*, 1954, vol. 173, June 24, pp. 100–3.

This article reports tests made on various types of austenitic nickel-chromium steel, to determine the range of composition to which the oxalic-acid etch test (proposed as a screening test for susceptibility to intercrystalline corrosion) is reliably applicable. (For particulars of this test see *Nickel Bulletin*, 1953, vol. 26, Nos. 5 and 8–9, pp. 88 and 155; 1954, vol. 27, No. 3, p. 52). Oxalic-acid tests on stabilized and unstabilized steels of various nickel and chromium contents showed (1) that for Types 302 and 304 (straight 18–8 grades), and also in Type 316 (molybdenum-containing steel of slightly higher nickel and chromium contents), behaviour in this test is a reliable criterion of susceptibility, and correlates with behaviour in the nitric-acid test, but (2) that with

Table II

	C %	Si %	Mn %	Ni %	Cr %	Other Elements %
Type 304L ..	0·03 max.	1·00 max.	2·00 max.	8-10	18-20	—
Type 316L ..	0·03 max.	1·00 max.	2·00 max.	10-14	16-18	Mo 1·75-2·50

		304L		316L	
		p.s.i.	t.s.i.	p.s.i.	t.s.i.
Tensile Strength	annealed	80,000- 90,000	35·75-40·25	80,000- 90,000	35·75-40·25
	cold-rolled	100,000-180,000	44·5 -80·5	100,000-150,000	44·5 -67·0
Yield Point	annealed	35,000- 45,000	15·5 -20·0	35,000- 55,000	15·5 -24·5
	cold-rolled	50,000-150,000	22·5 -67·0	55,000-125,000	22·5- 56·0
Elongation, in 2 in.	annealed	60-55%		70-60%	
	cold-rolled	50-10%		50-15%	
Brinell Hardness (bars)	annealed	135-185		135-185	
	cold-drawn	180-330		180-300	
Rockwell Hardness (sheet)	annealed	73-90B		70-90B	
	cold-rolled	10-35C		10-30C	

stabilized grades of the austenitic steels the microstructures obtained on etching with oxalic acid are not indicative of the corrosion rates occurring in boiling 65 per cent. nitric acid.

The authors make the following observations on the validity of the boiling nitric-acid test:—'Results on stabilized grades of steel prove that it is not correct to assume that low resistance to general attack by boiling nitric acid is an indication of susceptibility to intergranular attack. With the standard 18-8 grades nitric-acid (Huey) test data can be correlated with service tests, and the above assumption therefore has some basis, but no such correlation has been reported for the stabilized grades.

'Generally, the stabilized grades of stainless steel are considered less resistant to boiling nitric acid, but they are more resistant in many corrosive media than the regular 18-8 when both are free from intergranular susceptibility. This is particularly true for the titanium-stabilized grade, Type 321, which, after sensitizing, has a rather low and erratic resistance to boiling 65 per cent. nitric acid. This behaviour is characteristic of this particular concentration of nitric acid, since previous work showed that the corrosion rate of Type 321 steel, in the sensitized condition, decreases markedly as the concentration of the acid is lowered from 65 to 35 per cent. In solutions of 45 per cent. boiling nitric acid or in acid of a lower concentration there is little difference in the corrosion rates of Types 304 (straight 18-8), 347 (niobium-stabilized), and 321 (titanium-stabilized). It is not safe to judge resistance to other corrosive media from the results obtained in boiling 65 per cent. nitric-acid, and the Huey test should not be a general acceptance test for all stainless steels in all corrosive media. The results of oxalic-acid tests show that the low resistance of sensitized Type 321 steels to 65 per cent. boiling nitric acid is not the result of chromium-carbide precipitation at the grain boundaries, substantiating previous work, which showed that the presence of sigma phase is responsible for the high corrosion rate of titanium-stabilized steels. This sigma, formed from delta ferrite on sensitizing at 1250°F. (675°C.) is readily attacked by 65 per cent. nitric acid. The Huey test is unsuited for evaluating the tendency towards intergranular corrosion of Type 321 (titanium-stabilized) steel, and the electrolytic test is also ineffective for predicting corrosion rate of this steel in 65 per cent. nitric acid, since the oxalic acid test depends on precipitated chromium carbides, while the rate of corrosion of this steel in this particular medium is governed by the quantity of sigma phase present in the steel.'

Testing of Stainless Steels in Nitric Acid

J. E. TRUMAN: 'Factors Affecting the Testing of Stainless Steels in Boiling Concentrated Nitric Acid.' *Jnl. Applied Chemistry*, 1954, vol. 4, May, pp. 273-83.

The importance of a full understanding of the behaviour of high-chromium and chromium-nickel steels in concentrated nitric acid has increased during recent years, due to the requirements of the chemical industries, and to the extended use of the Huey-type corrosion test, in which the corroding medium is boiling 65 per cent. nitric acid. In connexion with the correct interpretation of laboratory tests in terms of probable service behaviour, it is essential that due consideration be given to certain factors which significantly influence the reaction of the steels with the acid. One of the most important of these variables is the acceleration of corrosion which is caused by dissolved chromium resulting from attack on the steel in the early stages of exposure. Observations of this effect have been recorded in the literature, and unpublished work reported by the present authors has shown that dissolved chromium can be oxidized by boiling 65 per cent. nitric acid and that the rate of corrosion is considerably affected by the state of oxidation of the chromium and by the condenser system employed in testing.

This paper covers work carried out to elucidate the effects of various factors on the accelerating influence of dissolved chromium: the variables investigated included the condenser system, the relative effects of ter- and sexi-valent chromium, the strength of the acid solution, and the composition of the steel tested. In all the experiments except those relating to the influence of composition of the steel, the test material was of the following composition:—carbon 0·12, silicon 0·74, manganese 1·42, chromium 18·26, nickel 14·03, niobium 1·39, per cent. After shearing, the plate samples were softened by air-cooling from 1050°C. and pickled for removal of scale. Full details are recorded of the results of the various series of tests made within the scope of the programme outlined above. From the data recorded the following conclusions are drawn:—

'For stainless steel, an almost uniform rate of corrosion with time can be obtained with boiling concentrated nitric acid if the content of dissolved steel in the acid is kept very low, but progressive acceleration occurs if dissolved steel is allowed to accumulate in the acid.

'The main factor controlling the rate of attack on a given steel by acid containing dissolved steel is the content of sexivalent chromium in the acid.

'The rate of attack bears an almost linear relationship to the amount of CrO_3 added to the acid, the curve falling off a little with higher concentrations of CrO_3.

'Tervalent chromium in solution has no accelerating effect, but can be oxidized by boiling nitric acid to the dangerous sexivalent state.

'For a given total content of chromium in the acid a balance is reached between the oxidation of chromium by the boiling acid and the reduction by the corroding steel.

'This balance is affected by the type of condenser used, since this controls the rate of removal of gaseous products of a reducing nature.

'The balance is also considerably affected by the concentration of the acid used—there is no danger of accelerated attack below a concentration of 50 per cent., but above 60 per cent. the effect increases sharply.

'Corrosion by nitric acid containing sexivalent chromium leaves the surface of stainless steel in a condition more susceptible to later attack in pure nitric acid. This may have significance in cyclic tests, even though

the acid is changed at each cycle, as a high rate of attack in one cycle will lead to an accelerated start in the next and to earlier acid contamination.

'The resistance of chromium and chromium-nickel steels to boiling pure nitric acid increases with the chromium content of the alloys, but if dissolved steel is allowed to accumulate in the test acid, an apparent inversion can take place at certain stages of testing with material of higher chromium content, presumably owing to the greater weight of chromium dissolved by the solution for a given amount of steel.

'The presence of sexivalent chromium in boiling nitric acid destroys the superior resistance from a high chromium content of the steel or from the presence of nickel, and with the 13 per cent. Cr–12 per cent. Ni steel, makes it inferior to the corresponding plain chromium steel.'

Corrosion Potential of Stainless Steels under Stress-Corrosion

T. P. HOAR and J. G. HINES: 'The Corrosion Potential of Stainless Steels during Stress-Corrosion.' *Jnl. Iron and Steel Inst.*, 1954, vol. 177, June, p. 248.

The authors of this note report experiments in which wire specimens of austenitic stainless steel were exposed, under stressed and unstressed conditions, to boiling 42 per cent. aqueous magnesium-chloride solution. Potential-time curves for an 18-10-3-1 chromium-nickel-molybdenum-titanium steel, (*a*) unstressed, and (*b*) stressed to two-thirds of its 0·1 per cent. proof stress, are given as typical of the observations made.

Unstressed specimens give results similar to those which have been reported for tin and iron in dilute salt solutions, and the curves obtained are explicable by similar stages in the development of corrosion:—

(1) the solution penetrates into pores in the surface oxide film, with anodic solution of the metal at its base. The corrosion potential falls as the film cathode becomes polarized by the corrosion current;
(2) hydroxide is precipitated within the pores, giving film repair, with associated rise in potential: the hydrogen-ion concentration within the pores increases;
(3) when the acidity within the pores becomes sufficiently high the metal begins to dissolve to soluble products: hydroxide dissolves, and the film is undermined. Substantial pitting starts, and the corrosion potential falls.

Moderately stressed specimens behave in a similar manner until the potential maximum is reached, except that the potential is 10–20 mv. less noble than that of an unstressed specimen. The potential then falls rapidly for a few minutes, until breakage of the wire, by stress-cracking, occurs. It then recovers, presumably through film repair of the fractured surfaces of the wire, which at that stage are in an unstressed condition.

Tensile tests made by the authors on specimens removed from the solution before complete breakage showed that cracking begins only at the start of the rapid fall in potential: extensometer measurements confirmed this conclusion, by indicating that no extension occurs until the start of the rapid drop in potential. The major part of the life of a moderately stressed specimen under the conditions used in these tests (and, it is believed, under other conditions of stress-corrosion) thus comprises the development of breakdown conditions in the surface film. Comparisons of time to failure of specimens so exposed therefore give information on development of film breakdown and crack initiation rather than on the rate of actual cracking. Measurements on more highly stressed specimens indicate that increased stress somewhat shortens the time required to set up film-breakdown conditions, but that it has little or no influence on rate of the cracking process once it has been initiated. On specimens exposed under low applied stress the cracking process does not begin until a long time after film-breakdown conditions have been established: in such conditions the existence of a relatively extensive corrosion pit appears to be essential to initiate cracking.

Potentials of Austenitic Nickel-Chromium Steel and Other Materials in Passivating Solutions

H. H. UHLIG and A. GEARY: 'Potentials of Iron, 18-8 and Titanium in Passivating Solutions.' *Jnl. Electrochemical Soc.*, 1954, vol. 101, May, pp. 215–24.

Potential measurements of iron exposed to chromate solutions, and parallel data on 18-8 chromium-nickel steel and titanium in other passivating electrolytes are presented as pertinent evidence to assist in elucidating the mechanism of passivation.

Electrolytic Polishing of Metals and Alloys: Reference Data

See abstract on p. 124.

Extrusion of Stainless-Steel Sections for Gas-Turbine Components

'Extrusion of Stainless Steel Sections.' *Engineer*, 1954, vol. 197, May 28, pp. 797–8.

Developments in the extrusion of stainless-steel tubing have been in progress in the works of Chesterfield Tube Company for over twenty years, but until recently, due to the toughness of stainless steel even at temperatures of 1200°–1250°C., problems of lubrication and tool construction have rendered some applications of the process uneconomic. The introduction of glass as a lubricant has, however, much increased tool life and has made possible much higher extrusion ratios than could be achieved with graphite lubricants. A wider field of application for extruded parts of stainless steel has thus been opened, one of the most important of which is the production of rings for use in jet engines. Extrusion of such rings is the subject of the present article.

The steel used is almost exclusively a titanium-stabilized 18-8 chromium-nickel type, but extrusions are also being produced for special purposes in higher-alloy grades, some of which contain tungsten, and in ferritic steels. The various stages in the production of

the rings are described and illustrated in this article, and various section designs are discussed. It is claimed that, due to its 'wrought' condition, material manufactured in extruded lengths from rolled billets has much better properties than cast material of similar composition, and that there is considerable economic advantage in this method of production.

Lead Coating of Stainless Steel for Drawing

'Lead Coating of Stainless Steel.' *Wire Industry*, 1954, vol. 21, May, p. 523.

In reply to an enquiry relating to lead coating of austenitic chromium-nickel steels prior to drawing, the following recommendations are made:—

(1) Ensure that the surface of the rod or wire is free from scale or other foreign matter.
(2) Immerse in a flux of 50 per cent. zinc chloride in the form of a concentrated solution in water, to which a small amount of ammonium chloride has been added.
(3) Dip in the lead bath, maintained at 375°-390°C.; on withdrawal drain, quench in water.

The lead used should be relatively pure, with low arsenic and antimony contents; 99·75 per cent. lead with bismuth up to 0·25 per cent. should be satisfactory. Alternatively, the following specification will ensure a satisfactory quality (all percentages except lead are maxima):—silver 0·002, copper 0·0025, arsenic, antimony and tin 0·015 max., bismuth 0·15, iron 0·002, zinc 0·002, per cent., lead difference.

For prevention of excessive oxidation of lead when using this coating method, a layer of tallow on the surface of the molten metal is recommended.

The importance of complete removal of lead after drawing is emphasized: de-leading is satisfactorily accomplished by immersion of the wire or strip in a 20 per cent. nitric-acid solution, which treatment may, if the work is dirty, be preceded by cleaning in an alkaline solution.

Influence of Rate of Drawing on the Properties of Stainless-Steel Wire

S. STORCHHEIM: 'Stainless-Steel Wire Properties are Affected by Draw Speed.' *Wire and Wire Products*, 1954, vol. 29, May, pp. 522-3, 564-7.

The work covered by this paper is an amplification of that reported by the author in *American Machinist*, 1952, vol. 96, July 21, pp. 124-5; *Nickel Bulletin*, 1953, vol. 26, No. 1, p. 24.

Two types of nickel-chromium steel wire were used, to A.I.S.I. specifications 302 and 304, respectively.

The analysis of the wires is shown below:—

Type	C %	Si %	Mn %	S %	P %	Mo %	Ni %	Cr %	Fe %
302 (set 1)	0·080	0·59	0·91	—	—	0·08	9·41	18·39	Bal.
(set 2)	0·12	0·70	1·50	0·019	0·025	—	9·40	18·04	Bal.
304 (set 1)	0·070	0·40	1·07	0·018	0·030	0·19	8·47	18·91	Bal.
(set 2)	0·071	0·45	0·97	0·030	0·034	0·25	9·85	18·04	Bal.

The results of the tests, shown in graphs and tables, indicate that variation in rate of drawing has definite effects on magnetic properties, tensile strength, and specific electrical resistance of wires of these steels.

With increasing rates of draw coercive force increased, while remanence, tensile strength and resistivity decreased. The variations in coercive force and remanence were considerable: those observed for tensile strength and specific resistance, although significant, were of smaller magnitude. For a given rate of draw, increase in nickel content of the steel was associated with increase in H_c and decrease in B_r and resistivity: for any one rate of draw, increased carbon resulted in higher tensile strengths. The observations made suggest that in an 18-8 stainless steel analysis which for some rates of drawing might not meet a given specification, it might, by correct choice of drawing speed, be possible to ensure properties meeting the requirements.

Corrosion-Resisting Materials for Plant Manufacturing Antibiotics

E. A. SCHOEFER: 'Castings Play Vital Rôle in Antibiotics.' *Chemical Engineering*, 1954, vol. 61, May, pp. 244, 246.

The pharmaceutical industry is becoming increasingly important as a consumer of corrosion-resisting materials, since in many of the processes involved even the slightest trace of a corrosion product would necessitate discarding a whole production batch of a drug. Cast nickel-containing alloys of the 18-8 and related types are in widespread use for plant in this industry: this article describes typical uses in plant employed in production of penicillin, terramycin and chloromycetin. The information given is based on large-scale experience in the works of manufacturers dealing with the respective products.

(1) *Penicillin.* In penicillin plant a molybdenum-containing grade of 18-8 is very widely employed, in view of contact with concentrated sulphuric acids and with caustic. In addition, metering devices and valves in the plant are variously required to resist corrosion under the following conditions:—chloroform (50°-70°F.), distilled water (70°F.), fresh-butter solution (70°F.), penicillin broth (50°-70°F.), amyl acetate (70°F.), wetting agent (50°-70°F.), sulphuric acid 98 per cent. (120°F.), potassium hydroxide, 15 per cent. (50°-70°F.), sodium hydroxide, 15 per cent. (100°F.).

(2) *Terramycin.* Service in plant producing this type of drug involves resistance to dilute sulphuric acid and other corrosives, as well as to frequent sterilization

with live steam. To these conditions the corrosion-resisting alloys of the cast iron-nickel-chromium type have been found to give good resistance.

(3) *Chloromycetin.* An example of the use of nickel-chromium-iron alloys in this type of plant is valves on large kettles, handling chloride solutions which are mainly basic in reaction, with pH ranging from 6 to 12 or 13. The solutions are at vacuum or atmospheric pressure and are used at temperatures up to 120°C. Such valves have been in service for periods up to four years, requiring only routine maintenance.

See also: 'Vital Role in Mass Production of Life-saving Antibiotics Played by Nickel-containing Stainless Steel.' *Inco*, 1954, vol. 26, No. 4, pp. 8–9.

Stainless-Steel Expansion Joints

'Metal Bellows.' *Welding Jnl.*, 1954, vol. 33, Apr., p. 379.

This brief note describes, with an illustration, large stainless-steel 'bellows' built by Solar Aircraft Company, San Diego, for use in a supersonic wind tunnel. These expansion joints, which will allow 'give' under air pressure or heat, are to be installed in the wind tunnel operated by the National Advisory Committee for Aeronautics, in Cleveland, Ohio. The thirteen joints built for this project ranged in size from 5 to 28 ft. Stainless-steel expansion joints of large size are being used in increasing quantity to provide for pipe expansion at elevated temperatures, e.g., in refineries, food-processing plants, petrochemical plants, power plants, and other installations in which temperature, pressure, corrosion, and erosion give rise to construction problems. At the other end of the scale, miniature versions of such expansion joints, as small as ½-in. in diameter, are being made for use in jet engines and other aircraft applications.

Nickel Alloys in the Liner 'Orsova'

'The Orient Liner 'Orsova': General Design and Accommodation, Machinery and Equipment.' *Engineering*, 1954, vol. 177, June 25, pp. 824–6; vol. 178, July 9, pp. 56–8: see also *Engineer*, 1954, vol. 197, June 25, pp. 923–6; vol. 198, July 2, pp. 7–10.

The liner 'Orsova', which has recently completed her first round voyage to Australia, is in various respects the most notable of the important vessels which have been constructed during recent years by Vickers-Armstrongs, Ltd., for the Orient Steam Navigation Company. She is the largest passenger liner yet built at that shipyard and one of the largest built anywhere in Britain during the post-war years, being 722 ft. 9 in. in overall length and having a gross registered tonnage of 28,800. She is designed to carry 681 first-class passengers and 813 in the tourist class, as well as general and refrigerated cargo.

In the description of the propelling machinery of the liner it is noted that Hecla A.T.V. (high-alloy nickel-chromium steel) has been used for the impulse blading of the turbines and that Monel has been extensively employed for reaction blading. The condenser tubes in the 'Orsova' are of 70–30 cupro-nickel alloy.

Monel Equipment in Fluorine-Disposal Plant

S. H. SMILEY and C. R. SCHMITT: 'Continuous Disposal of Fluorine: Reaction with Superheated Steam.' *Reprint of Paper from Industrial and Engineering Chemistry*, 1954, vol. 46, Feb., pp. 244–7; see abstract in *Nickel Bulletin*, 1954, vol. 27, No. 3, p. 51. Issued by International Nickel Co., Inc.; 4 pp.

Nickel-Clad Steel Tanks for Marine Transport of Caustic Soda

'First Custom-Built Tanker for Special Commodities Launched.' *Inco*, 1954, vol. 26, No. 4, pp. 4–7.
See also 'Launch Chemical Ship at Beth Quincy.' *Marine Engineering*, 1954, vol. 59, Feb., pp. 57, 62.

The first ocean-going tanker designed and constructed specifically for transport of liquid chemicals was launched at the Quincy Yard of Bethlehem Steel Company in December 1953, and has recently made its maiden voyage from Freeport, Texas, to ports on the East Coast of the U.S.A. The S.S. 'Marine Dow-Chem' will carry eleven different chemicals, in twenty-four centre tanks having a total capacity of over 3,500,000 gallons, and with wing tank capacity added, will carry approximately 5,000,000 gallons. She is an 18,000-ton vessel, 551 ft. long, 68 ft. beam, and can travel at a speed of 15 knots.

Four of the tanks, located near the stern of the ship, have been designed for the transport of 73 per cent. caustic soda. In order to avoid corrosion and embrittlement, the tanks have been constructed from nickel-clad steel, and solid nickel or nickel-clad steel has been specified for every piece of equipment coming into contact with the caustic soda. Prior to welding the nickel-clad steel tanks, research was carried out to develop a method which would ensure iron dilution below five per cent. Some account is given of the procedures used. The nickel piping used in the installation was welded by the inert gas-tungsten arc method, with helium as the protective medium.

The concentrated caustic carried in the tanks is used in the manufacture of rayon, cellulose film, soap, vegetable oil and other products of the special chemical industries.

Stainless-Steel Storage Tanks

R. H. SPIOTTA: 'Fabricating Stainless-Steel Tanks for Liquid Storage.' *Machinery* (*N.Y.*), 1954, vol. 60, May, pp. 157–64.

This article describes methods used by the Cherry-Burrell Corporation, Little Falls, N.Y., in fabrication of all-welded stainless nickel-chromium steel tanks for storage and/or refrigeration of milks, fruit juices, pharmaceutical products or other liquids in which freedom from contamination is a primary requisite. A feature of design in this plant is a 'cold-wall' construction, consisting of individual channels welded to a backing plate, to form circulating tubes for the refrigerant. This cold wall may run completely round the tank or round any portion of it, according to specific requirements. The channels extend round the periphery of the tank lining and terminate in two

header tubes which connect the open ends of all the channels at each side. All stages of production of the tanks are well illustrated.

Stainless Steel in Bone Surgery

'Clinical and Metallurgical Observations on the Corrosion of Stainless-Steel Screws used in Orthopaedic Surgery.' *Nature*, 1954, vol. 173, June 19, pp. 1186–7.

Correspondence arising out of letter from F. P. BOWDEN *et al.*, *ibid.*, Mar. 20, pp. 520–2; see *Nickel Bulletin*, 1954, vol. 27, No. 5, p. 96.

Nickel-containing Spring Alloys

See abstract on p. 135.

Nickel-containing Materials in Railway Equipment

'Rolling Stock for Argentine Railways.'
Railway Gazette, 1954, vol. 100, June 18, pp. 688–92.

This article deals with rolling stock of all-steel construction, supplied by Werkspoor N.V., Amsterdam, to the Argentine Railways. Design drawings, photographs, and a detailed description are given. It is noted that stainless steel has been extensively employed, e.g., in the interior finish of the coaches, in lavatory fitments, and in kitchen and food-service equipment. Parcel racks in the first-class carriages are of nickel-plated copper wire netting. Current supply for the lighting is supplied by Nife batteries.

Soil-Corrosion Tests on Bolt Materials

W. J. SCHWERDTFEGER: 'Electrical Measurements in the Selection of Bolt Materials for Service Underground.' *Jnl. of Research, Nat. Bur. Standards*, 1954, vol. 52, May, pp. 265–74; R.P. 2499.

Although failures of plain ferrous bolts underground are confined chiefly to severely corrosive environments, costs attributable to shutdowns and repairs are high. In highly corrosive soils bolt failures may occur before there is any severe effect on the structures to which they are coupled, and the main cause for the failure of the bolts is (apart from normally accelerated corrosion due to stress and edge effects) probably galvanic action between the bolts and the structures. The solution to the problem is therefore assumed to be the use of bolts fabricated from materials which are cathodic to the structures to which they are coupled. Two factors would call for consideration in using bolts of ferrous materials containing alloying constituents which would make the material cathodic to iron:—(1) cost, and (2) the possibility that, due to the potential difference between the coupled elements, excessive localized attack might occur on the adjacent anodic structure. Earlier investigations have, however, indicated that such excessive attack does not always take place.

The investigation reported in this paper was undertaken with a view to determining the extent to which electrical measurements might be useful in predicting the behaviour of bolts for use underground. Galvanic couples consisting of cast iron gland sections, coupled with bolts of steel and cast iron alloyed with small amounts of nickel and copper, high-alloy cast iron, and 70–30 nickel–copper alloy, were exposed to a corrosive soil, in the laboratory, for one year. The laboratory results confirm practical experience, in that although, according to Faraday's law, galvanic current between a cathodic bolt and a structure will produce weight loss, actually the local action on the structure is reduced by the galvanic current and the overall effect is apparently not detrimental.

Tables and figures, showing the degree of reduction in corrosion of bolts by making them cathodic to the gland sections which they coupled, indicate the beneficial influence of relatively small amounts of alloying constituents, especially 1·5–2 per cent. of nickel, and in the case of bolts of high-alloy cast iron and the nickel–copper alloy corrosion was almost negligible.

It is shown that the relative reduction in weight loss of the cathodic bolts can usually be predicted by potential changes of the bolts after placing the couples on open circuit. The relative degrees of protection produced by the galvanic currents on the various bolts, after exposure for one year, were also indicated by cathodic polarization curves.

Measurements of potential of low-alloy steels, made in puddled soil, showed that steels containing about 5 per cent. of chromium were cathodic, by about 50 mv., to unalloyed steel and cast iron, suggesting that they might be desirable bolt materials. A nickel content of about 3 per cent. in cast iron also had a significant effect.

Stress-Relief Heat-Treatment of Welded Austenitic Steels

W. L. FLEISCHMANN: 'Heat-Treatments of Welded Structures for Relief of Residual Stresses, with particular reference to Type 347 Stainless-Steel Weldments.' *Trans. Amer. Soc. Mechanical Engineers*, 1954, vol. 76, May, pp. 645–8.

In view of experience with carbon and low-alloy steels, there has been a tendency to assume that in other cases also beneficial results are to be obtained by stress-relief treatments of welded structures. The hardness variations and hydrogen embrittlement liable to occur in carbon and low-alloy steels on welding do not, however, occur in austenitic steels, and the American Society of Mechanical Engineers Boiler Code Committee, recognizing this fact, some time ago eliminated from its specifications the clause which made mandatory the stress-relieving of welded austenitic steel vessels. There remain, however, in certain cases, other reasons for modification of the stresses set up by welding, for example, avoidance of stress-corrosion, and the maintenance of close dimensional tolerances. Although mechanical methods may be used for relief of stress (e.g., peening) it has been general experience that stresses introduced into a structure below its operating temperature will relieve themselves in service and may cause dimensional instability. Thermal treatment above the probable service temperature is therefore necessary if strict dimensional stability is to be maintained.

Relaxation of stress is determined by the temperature of treatment. Complete and rapid relaxation occurs in the austenitic steels at temperatures above 1650°F.

(900°C.), but it has been reported that high-temperature annealing of fabricated Type 347 (niobium-stabilized 18-8) causes cracking, and it has even been stated that cracking after a treatment at 1350°F. (735°C.) may be expected. Arrested heating cycles (800°-1000°F.: 425°-540°C.), prior to treatment at the higher temperatures, have been suggested as a partial palliative, the aim of the intermediate step being to secure relaxation of peak stresses which might otherwise cause fracture at a higher temperature, at which the weld deposit or the weld-heat-affected zone might be brittle.

The experiments described in the present paper were undertaken to determine whether relaxation would occur in a relatively heat-resistant material such as the niobium-stabilized nickel-chromium steel, at the relatively low temperature of 1100°F. (595°C.), and whether, if relaxation occurred, such treatment would be useful in assuring dimensional stability of the structure operating over a range of temperature the upper limit of which was below that of the stress-relief treatment. Welded ring samples of the steel were subjected to various thermal treatments, to study their effectiveness in stress-relief. The results showed that heating at 1650°F. (900°C.) or above causes complete relaxation: at lower temperatures (1100°F.: 595°C. and 1200°F.: 650°C.) the amount of relaxation obtainable in reasonable periods depends on the magnitude of the residual stresses originally present. Further experiments, made on twisted wire specimens of the same steel, showed that relaxation occurred at relatively low temperatures: for example, heating at 1100°F. (595°C.) produced some untwisting, and established a pattern of residual stresses which did not cause any further movement during subsequent cycling within the range room temperature to 850°F. (455°C.).

The author supports the abolition, by the Boiler Code Committee, of the mandatory stress-relief clause, but points out that correctly selected thermal treatments can produce metallurgical changes which are of major importance in producing a condition suitable for specific types of service, irrespective of the stress-relief simultaneously obtained. In view of this possibility, it is suggested that the term 'thermal conditioning' is more suitable than 'stress-relieving', to describe the overall effect of heat-treatments of welded structures.

Specifications for Stainless Steel Welding Rods and Electrodes

'Sub-Committee Report on New Specifications for Bare Stainless Steel Welding Rods and Electrodes.' *Welding Jnl.*, 1954, vol. 33, May, pp. 433-7.

This report, by a joint A.W.S./A.S.T.M. Committee, forms the basis of the specifications which have recently been issued as A.W.S. A 5-9-53T and A.S.T.M. A 371-53T.

On the evidence of the relatively sparse quantitative data available, the Committee has considered it advisable to propose specifications which constitute a compromise between the wide limits desirable from the point of view of ease of manufacture and the narrow limits which would ensure that the properties of all materials which meet the specifications are constant. The report opens with a concise summary of the considerations upon which the chemical-compositions specifications are based. The limits proposed are then discussed, as affecting (1) austenitic chromium-nickel, and (2) straight-chromium grades, particular attention being given, under (1), to the balancing of welding rod and electrode compositions required to ensure freedom from weld cracking. In this connexion the Schaeffler diagram is correlated with a number of specification compositions proposed. Chromium : nickel ratios are discussed at length: manganese content and silicon-to-carbon ratio are also considered. In the straight-chromium grades the filler-metal compositions are essentially similar to the comparable base metals: exceptions are individually reviewed.

Soldering and Welding of Stainless Steels

'How to Solder and How to Weld Stainless Steel.' *Steel*, 1954, vol. 134, May 31, pp. 108-10.

Practical notes, with illustrations of suitable methods. The recommendations made are based on practice in the plant of Armco Steel Corporation.

Spot-Welding of Stainless-Steel Railway Carriages

'New Spot-Welding Method Re-Applies Stainless Steel Car Sidings.' *Welding Jnl.*, 1954, vol. 33, June, pp. 575-7.

Inspection of stainless-steel cars which had been in service for several years on the New York Central Railroad showed that, although the cars were still fit to give good service, some repair to the stainless-steel sides was desirable. One hundred and fifty of these cars are now undergoing such re-conditioning, by methods which are briefly described and illustrated in this note. The hundreds of spot welds required for the repair work are made by the 'Heliarc' process, using argon as the protective medium.

Joining of Tubes to Tube Sheets: Procedures Suitable for Various Materials

See abstract on p. 141.

Gas-Shielded Arc Processes for Cutting Nickel and Its Alloys

See abstract on p. 133.

PATENTS

Sintered Nickel Accumulator Plates

(1) A porous sintered plate for a nickel-cadmium accumulator is made by sintering a mixture of nickel-oxide powder and carbonyl-nickel powder round a wire mesh grid; the sintering is preferably carried out at a temperature of 1700°F. (925°C.).

(2) In a related patent a porous sintered plate is made by sintering a mixture comprising a major proportion of carbonyl-nickel powder (preferably 70-90 per cent.)

with a minor proportion of graphite (preferably 30–10 per cent.), round a nickel-plated wire mesh grid.
A. FLEISCHER, assignor to U.S. SECRETARY OF THE ARMY. *U.S. Pats.* 2,672,494 and 2,672,495.

(3) Large sheet electrodes for batteries are made by sintering metallic nickel powder, preferably carbonyl-nickel powder, onto both sides of a nickel gauze, and compressing it along crosswise lines defining lines of sub-division into smaller electrodes of the size required. Nickel or cadmium hydroxide is then introduced in the usual manner, the large sheets are sheared along the dividing lines, and the edges are cemented, e.g., with synthetic resin binder, to secure any loosened particles.
H. B. NICHOLS. *U.S. Pat.* 2,675,418.

(4) To improve the uniformity of highly porous objects, such as accumulator plates made by sintering nickel powder of density below 2 kg./L., the agglomerates in the powder are first broken down, e.g., by pressing gently through a 400/cm² sieve.
BADISCHE ANILIN- UND SODA-FABRIK. *French Pat.* 1,055,278.

Production of Sulphur-containing Nickel Anodes

High-purity nickel of good corrodibility is made by dissolving impure nickel anodes and depositing the pure nickel cathodically, using an electrolyte containing a small amount of a soluble sulphur compound, so that sulphur is deposited with the nickel. Suitable sulphur compounds are aryl sulphonates.
V. H. WAITE, assignor to McGEAN CHEMICAL CO. *Canad. Pat.* 500,934.

Aluminium-Coating of Nickel and Nickel Alloys

Cobalt, chromium, nickel, iron, or their alloys are thoroughly cleaned, treated with a flux comprising a fluoride compound of zirconium or titanium, and then brought into contact with molten aluminium. The flux may be applied in aqueous solution: K_2ZrF_6 and K_2TiF_6 are preferred.
H. LUNDIN. *Brit. Pat.* 707,261.

Electrodeposition of Bright Nickel

Bright nickel is electrodeposited from chloride, sulphate, and sulphate-chloride baths containing a polyalkylene amine of molecular weight above 100 and an aromatic nuclear sulphonic acid derivative.
D. G. ELLIS, assignor to HARSHAW CHEMICAL CO. *U.S. Pat.* 2,662,853.

An acid aqueous nickel-plating bath for the deposition of fine-grained bright coatings contains at least one nickel salt and a small percentage of at least one soluble fully esterified aliphatic ester of an unsaturated aliphatic polycarboxylic acid containing no triple bonds. Examples of the esters cited include trimethyl aconitate, di- (2-methoxy ethyl) maleate, and the dimethyl esters of fumaric acid, or itaconic acid. Sulphonamide, sulphonimide and sulphonic acid brighteners may also be present.
UDYLITE CORPN. *Brit. Pat.* 704,185.

Nickel Plating of Non-Ferrous Metals

In a process for nickel plating of non-ferrous metals, the base is first electrolytically coated with zinc. The zinc is polished, a flash coating of copper is applied, and the nickel can then be rapidly deposited from a bath containing (by weight per 100 litres of water), $NiSO_4$ 40–60 parts, Na_2SO_4 2–4 parts, $MgSO_4$ 2–4 parts, NaCl 0·3–0·6 parts, H_2O_2 (30 per cent.) 0·04–0·08 parts, boric acid 0·2–0·4 parts. The bath is operated at 1·8–2·5 volts, pH 6·4–6·9, temperature 50°–60°C.
E. FREIENSTEIN. *French Pat.* 1,059,259.

Bonding of Aluminium to Steel

In producing aluminium-clad steel the base is first plated with nickel to a thickness of 0·0003–0·0005 in. The oxide is removed from the aluminium surface and the two strips are heated to at least 920°F. (493°C.) in a protective atmosphere, and are bonded by pressure, preferably by rolling.
BOHN ALUMINIUM AND BRASS CORPN. *Brit. Pat.* 708,107.

Bonding of Rubber to Metal

The metal is coated, preferably electrolytically, with nickel, and the rubber or other material is bonded to it by a vulcanizing and moulding process.
E. G. FUSSELL and C. B. CHAMPION. *Brit. Pat.* 705,485.

Nickel Plating of Non-Metallic Surfaces

A non-metallic surface, e.g., plastic, is plated with nickel by first coating it with finely dispersed nuclei of a catalytic material or a less noble element than nickel, and subsequently immersing it in a bath consisting essentially of a nickel salt and a hypophosphite.
GENERAL AMERICAN TRANSPORTATION CORPN. *Belgian Pat.* 522,181.

Complex Nickel-Copper-Zinc Alloys

Alloys of high hardness, strength and elongation contain nickel 4–22·5, zinc 4–20, cadmium 0·5–3·5, per cent., copper not less than 55 per cent., iron 0·01–2·50, per cent.
W. M. WALLER and P. H. WALLER. *Brit. Pat.* 706,502.

Nickel-containing 'Heavy' Alloys

Complex 'heavy' alloys contain tungsten and/or molybdenum 62·5–90, chromium 1–22·5, nickel 5–10, copper 0·5, per cent. They are preferably prepared by compacting a mixture of the powdered constituents and sintering in pure dry hydrogen.
GENERAL ELECTRIC CO., LTD., D. J. JONES and A. LEACH. *Brit. Pat.* 711,698.

Nickel-base Pen-Nib Alloys

Alloys suitable for pen nibs contain chromium 33–40, molybdenum 5–10, cobalt 1–10, per cent., nickel balance.
EASTERBROOK PEN CO. (inventor, J. M. BLALOCK).

Temperature-Compensating Nickel-Iron Alloys

A temperature-responsive compensator for use in magnetic measuring instruments is made from an alloy containing nickel 29·25–31·5, chromium 0·3–2·9, manganese not more than 1, silicon not more than 0·5, per cent., iron balance. A preferred alloy (nickel 30–31, chromium 0·4–1·2, manganese 0·2–0·5, silicon 0·1–0·3, per cent.) has a linear temperature/permeability curve over the range −110°F. to +170°F.

R. E. SCHWYN and R. H. MITCHEL, assignors to GENERAL MOTORS CORPN. *U.S. Pat.* 2,668,944.

Alloys with carbon 0–0·5, silicon 0–0·7, manganese 0–1, nickel 30–50, chromium 3–15, molybdenum 0–5, per cent., balance iron, are annealed at above 800°C., rapidly cooled, and again annealed, in the range 400°–800°C.

A.G. FÜR UNTERNEHMUNGEN DER EISEN- UND STAHL-INDUSTRIE (inventor, H. FAHLENBRACH).

Complex Nickel-Aluminium-Iron-base Permanent-Magnet Alloys

Permanent magnets are made from alloys containing nickel 9·0–26, copper 1·0–8·0, cobalt 12–30, aluminium 5·5–10, titanium 4·0–7·0, silicon 0·4–2·0, per cent., iron balance. The total nickel+cobalt+copper percentage is required to be within specified limits, and ratios of silicon to aluminium and to titanium, and of titanium to aluminium are specified.

W. DANNÖHL, assignor to DEUTSCHE EDELSTAHLWERKE, A.G. *U.S. Pat.* 2,673,310.

Nickel-Iron Electrodes for Alkaline Accumulators

A mixture of 80–50 per cent. of iron powder with nickel powder is sintered, without compression, at 800°–1050°C., resulting in formation of a homogeneous alloy of iron and nickel in the form of a porous electrode carrier. The iron-nickel powder mixture is made by simultaneous decomposition of mixed iron and nickel compounds, e.g., by thermal decomposition of mixed carbonyls, or by reduction of mixed oxides by precipitation from mixed salt solutions.

P. A. C. JACQUIER. *Brit. Pat.* 708,736 (similar to *French Pat.* 1,057,783).

Ceramic-Metal Seals

Glazed ceramic is sealed to metal (preferably a nickel-iron alloy) by chemical bonding between the glaze and an oxide film on the metal surface.

K. L. G. SPARKING PLUGS, LTD. (inventors G. W. SHOOBERT and D. J. BLIGHT). *Brit. Pat.* 706,183.

Heat-Treatment of High-Alloy Cast Iron

Cast iron containing carbon 2·25–3·25, nickel 7–10, copper 3–4·5, chromium 1–4, silicon 1·5–3, manganese 0–1·2, per cent., balance iron, is hardened by heating to 1600°–1800°F. (870°–980°C.), and slowly cooling to below 900°F. (480°C.). It is specified that the content of nickel+copper shall not exceed 14 per cent.

MOND NICKEL CO., LTD. *Brit. Pat.* 709,302.

Nickel-Alloy Cast Iron Moulds

Moulds are chill-cast from low-phosphorus grey cast iron containing up to 1 per cent. of molybdenum, and up to 2·5 per cent. of nickel. After machining, the moulds are heated to 1500°–1550°F. (815°–840°C.), quenched, and subsequently annealed at a temperature between 50° and 100°F. (28° and 56°C.) higher than that at which the cast material for which they are to be used will enter the mould.

F. H. CHALKLEY and P. W. SEPHTON. *Canad. Pat.* 499,790.

Magnesium-Impregnation of Nickel and Nickel Steels

Metals, particularly nickel and nickel alloys such as nickel steels, are heat-treated while embedded in metallic borings or turnings containing from 0·02–0·5 per cent. of magnesium as an alloying ingredient.

MOND NICKEL CO., LTD. (inventor, E. H. BUCKNALL). *Brit. Pat.* 709,632.

Rare-Earth Metals in High-Alloy Steels

Alloys and steels which have good hot workability are of the following composition:—carbon up to 0·50 per cent., one or more of the metals chromium, molybdenum, tungsten 10–60 per cent. (with the proviso that there shall not be more than 30 per cent. of any one of the elements, nor less than 1 per cent. when two or more are present), nickel 4–70 per cent., and cerium and/or lanthanum in amounts which vary from 0·02–1·10 per cent. when 4 per cent. of nickel is present to 0·02–0·15 per cent. with 70 per cent. of nickel. Iron forms the balance, except that the following elements may also be present in specified amounts: copper, nitrogen, cobalt, manganese, silicon, titanium, niobium, tantalum, vanadium, beryllium, boron, aluminium, zirconium. In the chromium-containing alloys sulphur, or selenium and/or tellurium may also be present in specified amounts.

CARPENTER STEEL CO. (inventors, C. B. POST and D. G. SCHOFFSTALL). *Brit. Pat.* 708,820.

Nickel-Alloy Steels for Press and Stamping Tools

The tool steels specified contain carbon 0·35–0·55, chromium 1·0–1·5, nickel 3·5–4·5, vanadium 0–0·3, molybdenum 0–0·3, tungsten 0–0·3, per cent., balance iron.

ADMINISTRATION-SÉQUESTRE DES RÖCHLING'SCHE EISEN- UND STAHLWERKE, G.M.B.H. *French Pat.* 1,060,990.

High-Temperature Casting Alloys

Casting alloys having good strength and creep properties at high temperatures contain chromium 10–35, cobalt 10–50, molybdenum+tungsten 10–20, carbon 0·2–0·8, nickel at least 15, boron 0·01–0·1, per cent., with or without up to 20 per cent. in all of one or more of the following elements, each within specified limits: iron, zirconium, silicon, manganese, calcium, nitrogen, niobium, titanium, vanadium, aluminium, copper, magnesium, thorium. Preferably, the silicon content

does not exceed 1·0 per cent., and carbon is preferably within the limits 0·2–0·45, per cent.
MOND NICKEL CO., LTD. (inventors, W. BETTERIDGE and K. SACHS). *Brit. Pat.* 710,413.

Austenitic Steels containing Boron

Austenitic nickel-chromium steels claimed to be resistant to intercrystalline corrosion contain 0·001–0·1 per cent. of boron, and 1–6 per cent. of molybdenum.
GEBR. BÖHLER AND CO. *French Pat.* 1,054,575.

Steel for Exhaust Valves

Corrosion-resistant austenitic stainless steels suitable for I.C. engine exhaust valves operating in the presence of lead compounds contain carbon 0·08–1·50, chromium 12–30, nickel 2–35, manganese 3–12, molybdenum 1·5–9, nitrogen up to 0·60, per cent., silicon not above 0·45, per cent., balance iron.
P. A. JENNINGS, assignor to ARMCO STEEL CORPN. *U.S. Pat.* 2,671,726.

Joining of Austenitic to Ferritic Steel Tubing

An austenitic steel tube or pipe is connected to a tube or other element of ferritic steel by means of a transition piece consisting of lengths of austenitic and ferritic steel pipe welded together end to end. The inside of the transition piece is machined to remove the root bead from the weld, and the transition piece is welded to the austenitic and ferritic tubes, like metal to like.
BABCOCK and WILCOX, LTD. (inventor, T. B. WEBB). *Brit. Pat.* 706,015.

Metal tubes of different coefficients of thermal expansion, particularly tubes of austenitic and ferritic steels, are connected by a transition piece forming a taper joint welded or brazed over a large area between the two metals and welded like metal to like.
WESTDEUTSCHE MANNESMANNRÖHREN, A.G. *Brit. Pat.* 710,570.

Electrodes for Welding Complex Austenitic Steels

In electrodes for welding austenitic steels containing copper and molybdenum, the core wire contains nickel 19–28, chromium 13–19, molybdenum up to 15, copper up to 4, manganese up to 3, niobium/tantalum 0–2·5, per cent., iron balance. It is stated that no copper is required when the molybdenum content exceeds 5 per cent.
GEBR. BÖHLER AND CO. *French Pat.* 1,057,436.

Nickel-Chromium-Manganese Brazing Alloys

Alloys suitable for joining parts used at high temperatures contain chromium 5–20, manganese 35–63, nickel 32–50, per cent.
JOHNSON, MATTHEY AND CO., LTD. (inventor, J. C. CHASTON).

Nickel-Alloy Surfacing of Valves

A suitable surfacing alloy, e.g., containing carbon 0·10–1·0, silicon 2·0–6·0, manganese 0·1–2·0, chromium 10·0–20·0, nickel 50·0–80·0, per cent., balance iron, is applied, in the shape of a pre-formed ring, to a steel valve body and is melted in position by an induction coil placed in such a way that the ring is heated to a higher temperature than the valve body. Welding is completed by application of pressure.
DEUTSCHE EDELSTAHLWERKE, A.G. *Brit. Pat.* 707,555.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

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